

M-77-65-2 JUNE 1965

JUNCTURE STRESS FIELDS IN MULTICELLULAR SHELL STRUCTURES

VOL. III STRESSES AND DEFORMATIONS OF FIXED-EDGE SEGMENTAL CONICAL SHELLS

by

E. Y. W. TSUI
J. M. MASSARD
P. STERN

FACILITY FORM 602

N 66-13837
(ACCESSION NUMBER)
126
(THRU)

126
(CODE)
CR 68774
(PAGES)
INASA CR OR TMX OR AD NUMBER)
32
(CATEGORY)

GPO PRICE \$ _____
CFSTI PRICE(S) \$ _____
Hard copy (HC) 4.00
Microfiche (MF) 1.00
ff 653 July 65

June 1965

M-77-65-2

Technical Report

JUNCTURE STRESS FIELDS IN MULTICELLULAR
SHELL STRUCTURES

Final Report

Nine Volumes

Vol. III Stresses and Deformations of Fixed-Edge
Segmental Conical Shells

by

E. Y. W. Tsui
J. M. Massard
P. Stern

Contract NAS 8-11480 to National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Huntsville, Alabama

FOREWORD

This report is the result of a study on the numerical analysis of stresses and deformations of fixed-edge isotropic segmental conical shells of linearly varying thickness under uniform pressure, and gravitational loading, as well as linear thermal gradient across the thickness of the shell. Work on this study was performed by staff members of Lockheed Missiles & Space Company in cooperation with the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration under Contract NAS 8-11480. Contract technical representative was H. Coldwater.

This volume is the third of a nine-volume final report of studies conducted by the department of Solid Mechanics, Aerospace Sciences Laboratory, Lockheed Missiles & Space Company. Project Manager was K. J. Forsberg; E. Y. W. Tsui was Technical Director for the work.

The nine volumes of the final report have the following titles:

- Vol. I Numerical Methods of Solving Large Matrices
- Vol. II Stresses and Deformations of Fixed-Edge Segmental Cylindrical Shells
- Vol. III Stresses and Deformations of Fixed-Edge Segmental Conical Shells
- Vol. IV Stresses and Deformations of Fixed-Edge Segmental Spherical Shells
- Vol. V Influence Coefficients of Segmental Shells
- Vol. VI Analysis of Multicellular Propellant Pressure Vessels by the Stiffness Method
- Vol. VII Buckling Analysis of Segmental Orthotropic Cylinders under Uniform Stress Distribution
- Vol. VIII Buckling Analysis of Segmental Orthotropic Cylinders under Non-uniform Stress Distribution
- Vol. IX Summary of Results and Recommendations

SUMMARY

13837

This volume presents a set of basic equations for thin elastic conical shells and a digital program for the analysis of static response of segmental conical shells of linearly varying thickness with fixed edges under the following loading conditions:

- Uniform pressure
- Gravitational loading
- Linear thermal gradient through the thickness of shell

The problem is solved numerically by means of finite-difference technique, using a direct method of solving a large system of simultaneous equations. For completeness as a self-contained report, much of the information presented in Vol. II is repeated here.

Author

CONTENTS

Section	Page
FOREWORD	iii
SUMMARY	v
NOTATION	ix
1 INTRODUCTION	1
2 FORMULATION OF THE PROBLEM	5
2.1 Analytical Formulation	5
2.2 Boundary Conditions	17
2.3 Stresses in Skin	20
3 NUMERICAL ANALYSIS	20
3.1 Approximation of Derivatives	21
3.2 Difference Equations	23
4 DIGITAL PROGRAM	28
4.1 General Description	28
4.2 Numerical Example	29
4.3 Listing of the Program	57

NOTATION

$a_i, b_i, c_i, A, B, C,$	nondimensional parameters defined in text
$M(\), N(\), Q(\), u, v,$	
$w, x, Z(\), \theta, \rho, \kappa$	
D	flexural rigidity of shell = $Eh^3/12(1 - \nu^2)$
E	modulus of elasticity
F_i	boundary force at Station i
F^f	boundary forces of fixed-edge shell due to applied forces or thermal gradients
G	shear modulus
\hat{h}	thickness of shell
\bar{h}, \bar{k}	mesh spacings in x- and θ -coordinate directions
m, n	number of columns and rows of the mesh
i, j	dummy subscripts
k, k_{ij}	stiffness influence coefficients
$\hat{M}(\), \hat{N}(\)$	moments and stress resultants
$P(\)$	surface or body forces
$Q(\)$	transverse shears
R_i	concentrated forces at corners of shell boundaries in the z-direction
T	change of temperature
$\hat{u}, \hat{v}, \hat{w}$	displacement components in directions $\hat{x}, \hat{\theta},$ and \hat{z}

$\hat{x}, \hat{\theta}, \hat{z}$	shell coordinates
$\hat{\theta}_c$	angle subtending one-half width of conical segment
ξ, η	orthogonal coordinates along boundaries of shell
δ_i	boundary deformations (displacements or rotations) of Station i
$\epsilon(\), \gamma(\)$	direct and shear strains
$\chi(\)$	changes of curvature or torsion of middle-surface
ν	Poisson's ratio
$\omega(\)$	rotations of the normal at the middle-surface
$(\), \hat{x}$	$\frac{\partial(\)}{\partial \hat{x}}$
$(\)_i^j$	functions at a discrete point i, j where i, j implies the \hat{x} - and $\hat{\theta}$ -directions respectively
ϵ^T	thermal strain = coefficients of linear expansion times the change of temperature, T
Φ	rotation in the middle-surface around the normal
$\hat{(\)}$	dimensional quantities
ϕ_2	angle defining cone axis orientation relative to gravitational force
ϕ_3	half-cone angle
\hat{x}_o, \hat{x}_L	dimensional distances defining the near and far boundaries of shell panel from the apex
\hat{h}_o	dimensional thickness of shell at \hat{x}_o

Additional notations and symbols are defined in the text.

Section 1
INTRODUCTION

As a result of an investigation of juncture stress fields peculiar to the multicellular pressure vessels (Fig. 1), a theory for the prediction of the membrane and bending stresses and the corresponding deformations for such shell structures was formulated.*

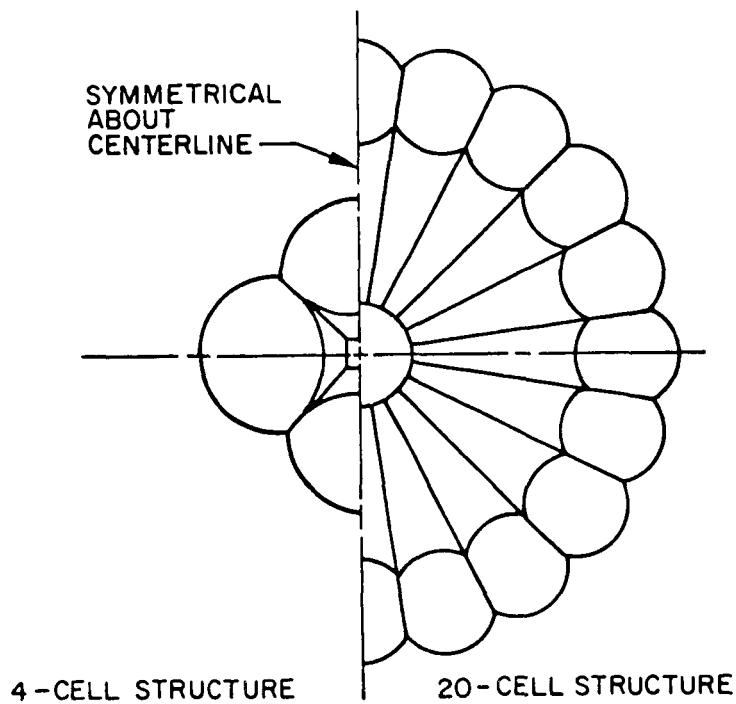


Fig. 1 Multicellular Shell Structure

*"Investigation of Juncture Stress Fields in Multicellular Shell Structures," by E. Y. W. Tsui, F. A. Brogan, J. M. Massard, P. Stern, and C. E. Stuhlman, Technical Report M-03-63-1, Lockheed Missiles & Space Company, Sunnyvale, Calif., Feb 1964 - NASA CR-61050

Due to the fact that analytic solutions are still lacking, it was decided to solve the problem numerically by means of finite-difference technique. To ensure the feasibility of such a numerical solution, a direct method of solving large matrices with a high-speed digital computer was also developed.

According to the previous work, if the stiffness or displacement method is used, the total forces and hence the corresponding stresses along the juncture of the shell segments (Fig. 2) may be expressed concisely in the following matrix form

$$F = k\delta + F^f \quad (1.1)$$

where k is the stiffness matrix, δ are the deformations, and F^f are the fixed-end forces due to applied loads or thermal gradients. In view of this situation, it is logical to solve the problem systematically by the established general procedure of analysis already described.* This procedure may be stated briefly as follows:

1. Determination of the fixed-end forces, F^f , along the boundary as well as stresses and deformations in the interior of shell segments due to loads
2. Determination of the influence coefficients, k_{ij} , along the boundaries of shell segments, i.e., the induced forces at points i due to unit deformations ($\delta = 1$) at points j
3. Determination of the actual deformations, δ , along the shell boundaries; this requires the satisfaction of both compatibility and equilibrium conditions at the junctures of the structure

Once all the work involved in these three steps is completed, the total stresses and deformations in the specific discrete interior locations may be obtained.

*"Investigation of Juncture Stress Fields in Multicellular Shell Structures," by E. Y. W. Tsui, F. A. Brogan, J. M. Massard, P. Stern, and C. E. Stuhlman, Technical Report M-03-63-1, Lockheed Missiles & Space Company, Sunnyvale, Calif., Feb 1964 - NASA CR-61050.

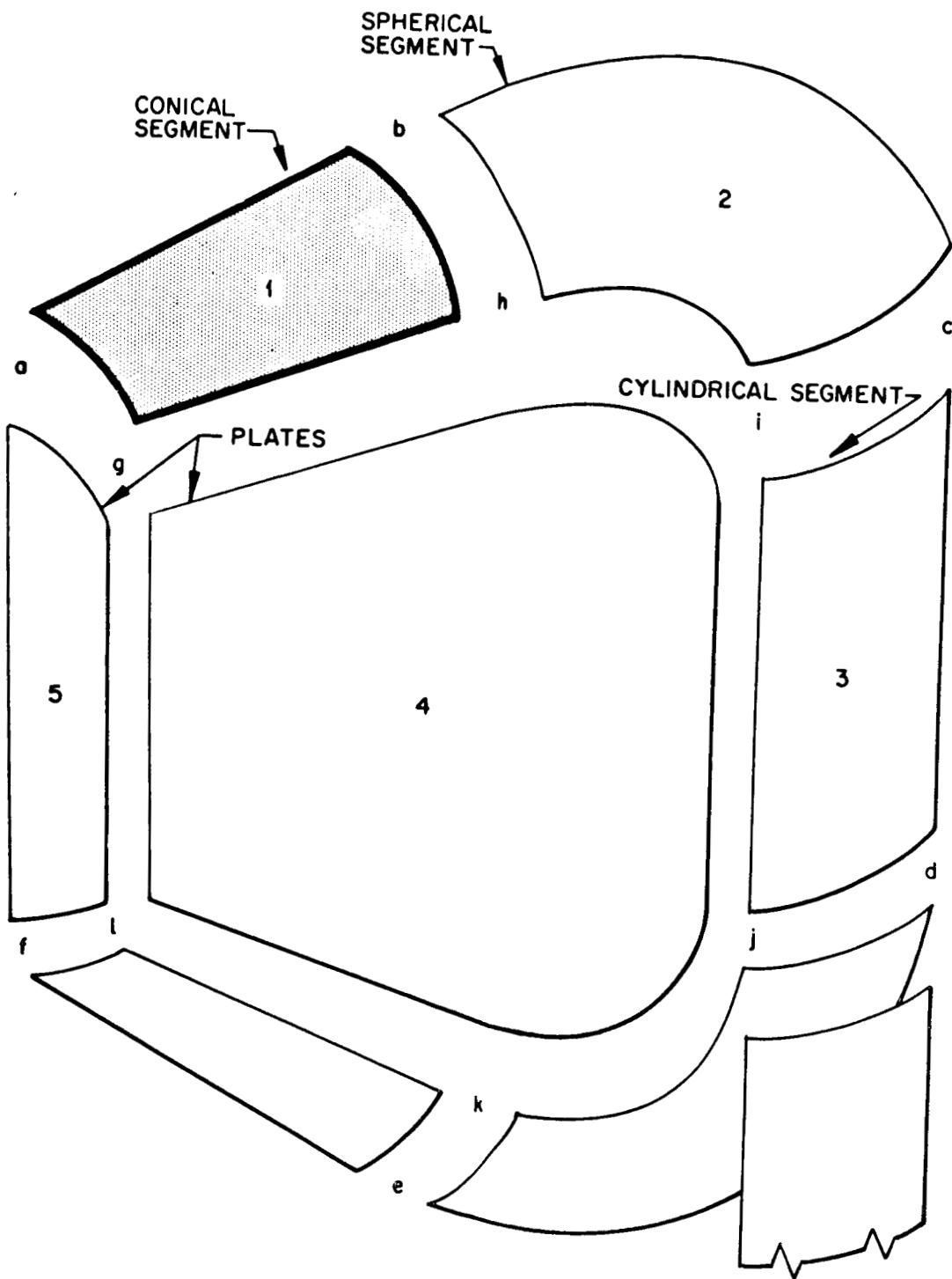


Fig. 2 Basic Shell Elements of Multicellular Structure

This volume presents results of the work involved in Step 1 only and covers the following items:

- Nondimensional formulation of the problem
- Detailed description of a workable digital program for the generation of solutions
- Example problem including tabulation of stresses and deformations of an isotropic segmental conical shell with fixed edges under uniform internal pressure

Section 2
FORMULATION OF PROBLEM

The necessary analytical expressions for a conical shell have already been given.* In order that this report be complete in the sense of equations, all the required equations are presented. Further, boundary conditions for a boundary which coincides with coordinate axes are given. Finally, the governing equations are written in difference form, and the ordering of the equations is given so that they can be solved by the "direct method" described in Vol. I.

2. 1 ANALYTICAL FORMULATION

The geometry of the conical panel under consideration is shown in Fig. 3. Symmetry is noted in the θ -direction. This condition does not restrict the equation system which follows; it only affects the method of solution.

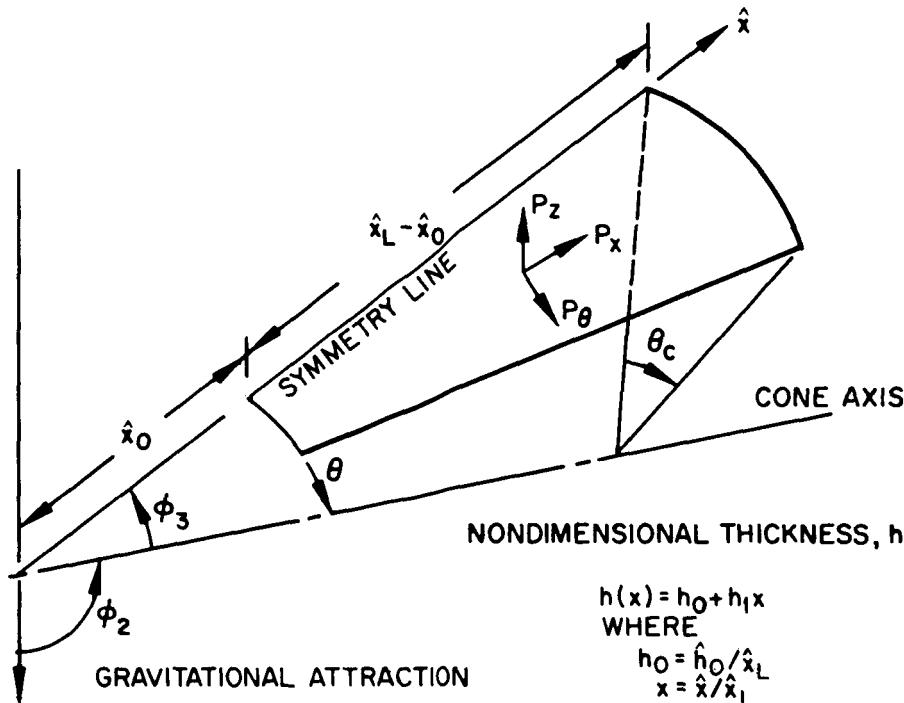


Fig. 3 Geometry of Conical Shell Panel.

*"Investigation of Juncture Stress Fields in Multicellular Shell Structures," by E. Y. W. Tsui, F. A. Brogan, J. M. Massard, P. Stern, and C. E. Stuhlman, Technical Report M-03-63-1, Lockheed Missiles & Space Company, Sunnyvale, Calif., Feb 1964 — NASA CR-61050.

To obtain a formulation which will yield solutions covering a wide range of shell parameters, all geometrical and dependent variables have been nondimensionalized and normalized in the following manner:

For the coordinate system

$$x = \hat{x}/\hat{x}_L \quad (2.1a)$$

$$\theta = \hat{\theta}/\theta_c \quad (2.1b)$$

$$z = \hat{z}/\hat{x}_L \quad (2.1c)$$

$$\bar{h} = x/n \quad (2.1d)$$

$$\bar{k} = \theta/m \quad (2.1e)$$

For the dependent variables

$$u = \hat{u}/\hat{x}_L \quad (2.2a)$$

$$v = \hat{v}/\hat{x}_L \quad (2.2b)$$

$$w = \hat{w}/\hat{x}_L \quad (2.2c)$$

also

$$\chi_x = \bar{\chi}_x \hat{x}_L \quad (2.2d)$$

$$\chi_\theta = \bar{\chi}_\theta \hat{x}_L \quad (2.2e)$$

$$\chi_{x\theta} = \bar{\chi}_{x\theta} \hat{x}_L \quad (2.2f)$$

For the geometric parameters

$$h_o = \hat{h}_o/\hat{x}_L$$

$$h(x) = \text{linear thickness variation (nondimensional)} \\ = h_o + h_1 x$$

$$x_o = \hat{x}_o/\hat{x}_L = \text{nondimensional distance defining one boundary of shell panel} \\ h_1 = \text{rate of change of thickness in } x$$

With these relationships, the basic shell equations can be written as shown in Secs. 2.1.1 through 2.1.4.

2.1.1 Rotation-Displacement Relations

Positive displacements and rotations of the middle-surface (Fig. 4) are shown in Fig. 5 and are related by the equations

$$\omega_x = -w_{,x} \quad (2.3a)$$

$$\omega_\theta = v/x \tan \phi_3 - w_{,\theta}/x \theta_c \sin \phi_3 \quad (2.3b)$$

$$\Phi = [v_{,x} - (1/x \theta_c \sin \phi_3) u_{,\theta} + v/x]/2$$

2.1.2 Strain-Displacement Relations

The strains of the middle-surface are related to displacements by

$$\bar{\epsilon}_x = u_{,x} \quad (2.4a)$$

$$\bar{\epsilon}_\theta = [(1/\theta_c \sin \phi_3)v_{,\theta} + u + (1/\tan \phi_3)w]/x \quad (2.4b)$$

$$\bar{\gamma} = v_{,x} + (1/x)v + (1/x \theta_c \sin \phi_3)u_{,\theta} \quad (2.4c)$$

and the changes of curvature and torsion are

$$\chi_x = -w_{,xx} \quad (2.5a)$$

$$\chi_\theta = [(\cos \phi_3)v_{,\theta} - (1/\theta_c \sin \phi_3)w_{,\theta\theta}]/\theta_c x^2 \sin^2 \phi_3 - (1/x)w_{,x} \quad (2.5b)$$

$$\chi_{x\theta} = -[w_{,x\theta} - (1/x)w_{,\theta}]/x \theta_c \sin \phi_3 + [v_{,x} - (1/x)v]/x \tan \phi_3 \quad (2.5c)$$

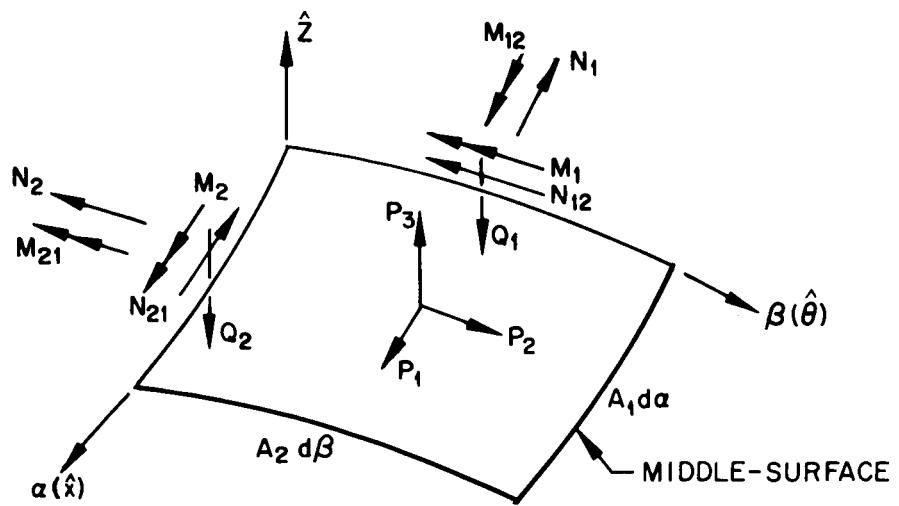


Fig. 4 Stress Resultants, Moments, and Loads

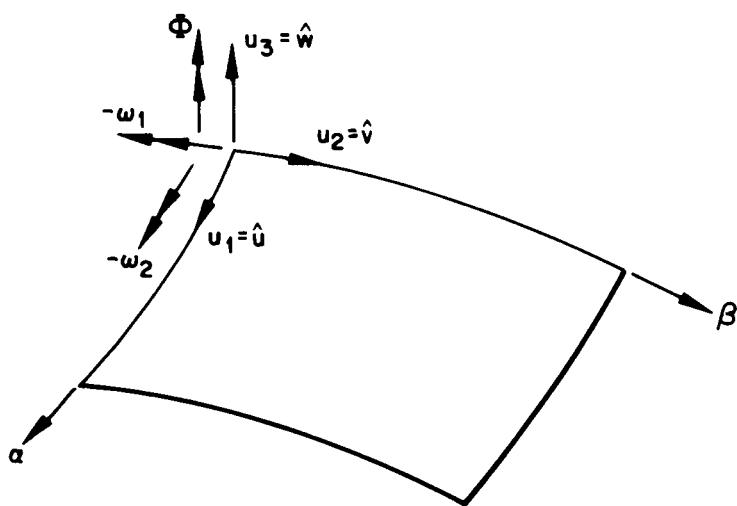


Fig. 5 Displacements and Rotations

The strains at a distance z from the middle-surface are given by

$$\epsilon_x = \bar{\epsilon}_x + z\chi_x \quad (2.6a)$$

$$\epsilon_\theta = \bar{\epsilon}_\theta + z\chi_\theta \quad (2.6b)$$

$$\gamma_{x\theta} = \bar{\gamma}_{x\theta} + 2z\chi_{x\theta} \quad (2.6c)$$

2.1.3 Constitutive Relations

Positive stress resultants are shown in Fig. 4. Nondimensional stress resultants are related to them and to strains by the following equations:

$$N_x = [\hat{N}_x(1 - \nu^2)/Eh] = \bar{\epsilon}_x + \nu\bar{\epsilon}_\theta + N^T \quad (2.7a)$$

$$N_\theta = [\hat{N}_\theta(1 - \nu^2)/Eh] = \bar{\epsilon}_\theta + \nu\bar{\epsilon}_x + N^T \quad (2.7b)$$

$$N_{x\theta} = [\hat{N}_{x\theta}/hG] = \bar{\gamma} + (h^2/6x \tan \phi_3)\chi_{x\theta} \quad (2.7c)$$

$$N_{\theta x} = [\hat{N}_{\theta x}/hG] = \bar{\gamma} \quad (2.7d)$$

$$M_x = [\hat{M}_x x_L/D] = \chi_x + \nu\chi_\theta + M^T \quad (2.7e)$$

$$M_\theta = [\hat{M}_\theta x_L/D] = \chi_\theta + \nu\chi_x + M^T \quad (2.7f)$$

$$M_{x\theta} = M_{\theta x} = [\hat{M}_{x\theta} x_L/D] = (1 - \nu)\chi_{x\theta} \quad (2.7g)$$

$$\begin{aligned} Q_x &= \left[\hat{Q}_x x_L^2/D \right] = \chi_{x,x} + \nu\chi_{\theta,x} + \frac{(1-\nu)}{x}(\chi_x - \chi_\theta) \\ &\quad + (3h_1/h_o)(\chi_x + \nu\chi_\theta) + \frac{(1-\nu)}{\theta c_x \sin \phi_3} \chi_{x\theta,\theta} \\ &\quad + M_{x,x}^T + (3h_1/h_o)M^T \end{aligned} \quad (2.7h)$$

$$Q_\theta = \left[\frac{Q_{\theta X} L}{D} \right] = \frac{1}{x \sin \phi_2} \left[\chi_{\theta, \theta} + \nu \chi_{X, \theta} \right] + (1 - \nu) \chi_{X \theta, X} \\ + (1 - \nu) (2/x + 3h_1/h_o) \chi_{X \theta} + \frac{1}{x \sin \phi_3} M^T_{,\theta} \quad (2.7i)$$

where

$$N^T = \left[\frac{N^T (1 - \nu^2)}{Eh} \right] = - (1 + \nu) \frac{1}{h} \int_{-h/2}^{h/2} \alpha T dz \\ M^T = \left[\frac{M^T_{X L}}{D} \right] = - \frac{12(1 + \nu)}{h^3} \int_{-h/2}^{h/2} \alpha T z dz$$

and

T = temperature change relative to a zero thermal stress condition
 α = thermal coefficient of expansion

2.1.4 Governing Differential Equations

The governing differential equations for a conical shell in terms of the displacement components u , v , and w are given by

$$a_1 u_{,XX} + a_2 u_{,\theta\theta} + a_3 u_{,X} + a_4 u + a_5 v_{,X\theta} + a_6 v_{,\theta} + a_7 w_{,X} + a_8 w = A \quad (2.8a)$$

$$b_1 u_{,X\theta} + b_2 u_{,\theta} + b_3 v_{,XX} + b_4 v_{,\theta\theta} + b_5 v_{,X} + b_6 v + b_7 w_{,XX\theta} \\ + b_8 w_{,\theta\theta\theta} + b_9 w_{,X\theta} + b_{10} w_{,\theta} = B \quad (2.8b)$$

$$c_1 u_{,X} + c_2 u + c_3 v_{,XX\theta} + c_4 v_{,\theta\theta\theta} + c_5 v_{,X\theta} + c_6 v_{,\theta} + c_7 w_{,XXXX} \\ + c_8 w_{,XX\theta\theta} + c_9 w_{,\theta\theta\theta\theta} + c_{10} w_{,XXX} + c_{11} w_{,X\theta\theta} + c_{12} w_{,XX} \\ + c_{13} w_{,\theta\theta} + c_{14} w_{,X} + c_{15} w = C \quad (2.8c)$$

where

$$a_1 = -h$$

$$a_2 = - \left[(1 - \nu) / 2 \theta_c^2 \sin^2 \phi_3 \right] (h/x^2)$$

$$a_3 = - [(1/x)h + h_1]$$

$$a_4 = [(1/x)h - \nu h_1]/x$$

$$a_5 = - [(1 + \nu) / 2 \theta_c \sin \phi_3] (h/x)$$

$$a_6 = [(3 - \nu)h/2x - \nu h_1]/x \theta_c \sin \phi_3$$

$$a_7 = -\nu \cot \phi_3 h/x$$

$$a_8 = \cot \phi a_4$$

$$b_1 = a_5$$

$$b_2 = - [(3 - \nu)h/2x + (1 - \nu)h_1/2]/x \theta_c \sin \phi_3$$

$$b_3 = - \left[1 + \left(1/3 \tan^2 \phi_3 \right) (h/x)^2 \right] (1 - \nu)h/2$$

$$b_4 = - \left[1 + \left(1/12 \tan^2 \phi_3 \right) (h/x)^2 \right] h / (\theta_c x \sin \phi_3)^2$$

$$b_5 = - \left[(h/x) + h_1 - \left(1/3 \tan^2 \phi_3 \right) (h/x)^3 + \left(h_1 / \tan^2 \phi_3 \right) (h/x)^2 \right] (1 - \nu)/2$$

$$b_6 = -(1/x)b_5$$

$$b_7 = \left(\cos \phi_3 / 12 \theta_c \sin^2 \phi_3 \right) (h/x)^2 (2 - \nu)h$$

$$b_8 = \left(\cos \phi_3 / 12 \theta_c^3 \sin^4 \phi_3 \right) (h/x)^3 / x$$

$$b_9 = - \left[(1 - 2\nu)(h/x)^3 - 6(1 - \nu)h_1(h/x)^2 \right] \cos \phi_3 / 12 \theta_c \sin^2 \phi_3$$

$$b_{10} = [-1 + (h/x - 3h_1)(1 - \nu)h/6x] h \cos \phi_3 / x^2 \theta_c \sin^2 \phi_3$$

$$c_1 = -a_7$$

$$c_2 = h \cot \phi_3 / x^2$$

$$c_3 = -(2 - \nu)h^3 \cot \phi_3 / 12 \theta_c x^2 \sin \phi_3$$

$$c_4 = -h^3 \cot \phi_3 / 12 \theta_c^3 x^4 \sin^3 \phi_3$$

$$c_5 = [h/x - 2h_1]h^2 \cot \phi_3 / 4 \theta_c x^2 \sin \phi_3$$

$$c_6 = \left[1 + h^2/3x^2 - 3h_1h/4x + \nu h_1^2/2 \right] h \cot \phi_3 / \theta_c x^2 \sin \phi_3$$

$$c_7 = h^3/12$$

$$c_8 = h^3 / 6(\theta_c x \sin \phi_3)^2$$

$$c_9 = h^3 / 12 \theta_c^4 x^3 \sin^4 \phi_3$$

$$c_{10} = [h/x + 3h_1]h^2/6$$

$$c_{11} = -[h/x - 3h_1]h^2 / 6(\theta_c x \sin \phi_3)^2$$

$$c_{12} = -\left[(h/x)^2 - 3(2 + \nu)h_1h/x - 6h_1^2 \right] h/12$$

$$c_{13} = \left[4h^2/x^2 - 9h_1h/x + 6\nu h_1^2 \right] h/12(\theta_c x \sin \phi_3)^2$$

$$c_{14} = \left[(h/x)^2 - 3h_1h/x + 6\nu h_1^2 \right] h/12x$$

$$c_{15} = h \cot^2 \phi_3 / x^2$$

In general, the loading functions are

$$A = (1 - \nu^2)P_x/E + (hN^T)_{,x}$$

$$B = (1 - \nu^2)P_\theta/E + (hN^T)_{,\theta}/\theta_c x \tan \phi_3 + (h^3 M^T)_{,\theta}/12 \theta_c x^2 \tan \phi_3 \sin \phi_3$$

$$C = (1 - \nu^2)P_z/E - (hN^T)/x \tan \phi_3 + \left(\frac{h^3 M^T}{12} \right)_{,xx} + h^3 M^T_{,x}/12 x + (h^3 M^T)_{,\theta\theta}/x^2 \theta_c^2 \sin^2 \phi_3$$

where in general,

$$(hN^T) = -(1 + \nu)\alpha \int_{-h/2}^{h/2} T dz$$

$$(h^3 M^T) = -12(1 + \nu)\alpha \int_{-h/2}^{h/2} T z dz$$

and

T = temperature change relative to a zero thermal stress condition

α = thermal coefficient of expansion

As mentioned in Sec. 4, the digital computer program which has been prepared has three options for loading. The specialization of the loading functions given above for each of these options follows:

- Uniform pressure

$$A = B = 0$$

$$C = (1 - \nu^2)P_z/E = 1.0$$

This will yield solutions normalized by C . For a given pressure, modulus, and value of Poisson's ratio, C can be found. The values of the dimensional

dependent variables, \hat{u} , \hat{v} , and \hat{w} , can be computed from the nondimensional quantities, u , v , and w , obtained from the computer solution as

$$\hat{u} = u \hat{c} x_L$$

$$\hat{v} = v \hat{c} x_L$$

$$\hat{w} = w \hat{c} x_L$$

where

$$\hat{c} = (1 - \nu^2) P_z / E$$

- Gravitational loading (see Fig. 3 for definition of terms)

$$A = \frac{h}{h_o} (\cos \phi_2 \cos \phi_3 - \sin \phi_2 \sin \phi_3 \cos \theta_c \theta)$$

$$B = \frac{h}{h_o} (\sin \phi_2 \sin \theta_c \theta)$$

$$C = -\frac{h}{h_o} (\cos \phi_2 \sin \phi_3 + \sin \phi_2 \cos \phi_3 \cos \theta_c \theta)$$

Dimensional displacements can be computed from the nondimensional solutions, u , v , and w , through the relationships:

$$\hat{u} = ux_L \hat{\rho} h_o (1 - \nu^2) / E$$

$$\hat{v} = vx_L \hat{\rho} h_o (1 - \nu^2) / E$$

$$\hat{w} = wx_L \hat{\rho} h_o (1 - \nu^2) / E$$

where

$\hat{\rho}$ = material density

- Linear thermal gradient through the thickness of the shell

For this special case let $T = T_1 + T_2 z/h$ where $T_1 = 1/2(T_e + T_o) - 2T_o$; $T_2 = (T_e - T_i)$; T_e is the temperature at the external surface; T_i , that at the internal surface and T_o , that at which the thermal stress is zero.

Then in nondimensional form,

$$(hN^T) = -(1 + \nu)\alpha T_1 h$$

$$(h^3 M^T) = -(1 + \nu)\alpha T_2 h^2$$

where

$$h = h_0 + h_1 x$$

The loading functions in nondimensional form then becomes

$$A = -(1 + \nu)\alpha T_1 h_1$$

$$B = 0$$

$$C = \frac{(1 + \nu)\alpha T_1 h}{x \tan \phi_3} - \frac{(1 + \nu)\alpha T_2 h_1^2}{6} - \frac{(1 + \nu)\alpha T_2 h h_1}{6x}$$

Dimensional displacements can be computed from the nondimensional solutions for u , v , and w through the relationships

$$\hat{u} = ux_L$$

$$\hat{v} = vx_L$$

$$\hat{w} = wx_L$$

2.2 BOUNDARY CONDITIONS

The boundary conditions have already been given* for an arbitrary shell with a smooth boundary curve. These boundary conditions are in terms of displacements and stress resultants. If the boundary curve is not smooth, it is possible that a concentrated load must be applied at the slope discontinuity. This concentrated load can be established by use of the work done by the boundary forces,

$$W^b = \int_c^t \left[\left(N_\eta + \frac{M_{\xi\eta}}{R} \right) u_\eta + \left(N_\xi - \frac{M_{\xi\eta}}{R_\eta} \right) u_\xi + Q_3 w + M_\xi \omega_\eta - \frac{M_{\xi\eta}}{A_\eta} \frac{\partial w}{\partial \eta} \right] d\xi \quad (2.9)$$

The last term in this equation can be integrated by parts to yield

$$W^b = \int_c^t \left[\left(N_\eta + \frac{M_{\xi\eta}}{R} \right) u_\eta + \left(N_\xi - \frac{M_{\xi\eta}}{R_\eta} \right) u_\xi + \left(Q_3 + \frac{1}{A_\eta} \frac{\partial M_{\xi\eta}}{\partial \eta} \right) w + M_\xi \omega_\eta \right] d\xi - \sum_{i=1}^k R_i w(i) \quad (2.10)$$

where

$$R_i = [M_{\xi\eta}(\eta_2) - M_{\xi\eta}(\eta_1)]_i$$

Thus R_i is a concentrated load in the direction of z at which the boundary curve has a discontinuous slope.

*"Investigation of Juncture Stress Fields in Multicellular Shell Structures," by E. Y. W. Tsui, F. A. Brogan, J. M. Massard, P. Stern, and C. E. Stuhlman, Technical Report M-03-63-1, Lockheed Missiles & Space Company, Sunnyvale, Calif., Feb 1964 — NASA CR-61050.

At this point a specific boundary curve is considered. This is shown in Fig. 6 as \overline{abcd} . The boundary forces for various sections of this boundary curve are given by equations

\overline{ab} :

$$\bar{N}_\eta = N_{x\theta} + \frac{h^2}{x(1 - \nu) \tan \phi_3} M_{x\theta}$$

$$\bar{N}_\zeta = N_x$$

$$\bar{Q} = - \left[Q_x + \frac{1}{x\theta_c \sin \phi_3} M_{x\theta, \theta} \right]$$

$$\bar{M}_\zeta = M_x$$

$$R_b = 2M_{x\theta}$$

\overline{bc} :

$$\bar{N}_\eta = -N_{\theta x}$$

$$\bar{N}_\zeta = N_\theta$$

$$\bar{Q} = [Q_\theta + M_{\theta x, x}]$$

$$\bar{M}_\zeta = M_\theta$$

\overline{cd} :

$$\bar{N}_\eta = N_{x\theta} + \frac{h^2}{x(1 - \nu) \tan \phi_3} M_{x\theta}$$

$$\bar{N}_\zeta = N_x$$

$$\bar{Q} = Q_x + \frac{1}{x\theta_c \sin \phi_3} M_{x\theta, \theta}$$

$$\bar{M}_\zeta = M_x$$

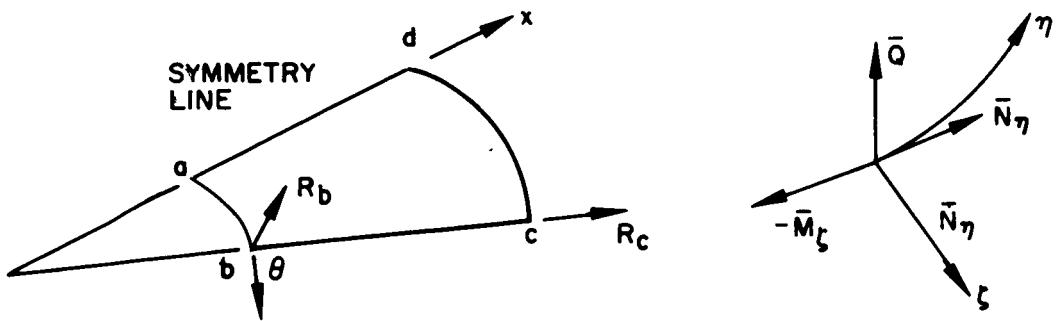


Fig. 6 Boundary Curve and Forces

At the corners b and c there is a possible reaction load given by

$$R_i = 2M_{x\theta}(b; c)$$

For a fixed-edge conical shell, the displacement components are all zero. Thus, for the boundary curve \overline{abcd} , the required boundary conditions are

$$\overline{ab}: \quad u \equiv v \equiv w \equiv \frac{\partial w}{\partial x} \equiv 0$$

$$\overline{bc}: \quad u \equiv v \equiv w \equiv \frac{\partial w}{\partial \theta} \equiv 0$$

$$\overline{cd}: \quad u \equiv v \equiv w \equiv \frac{\partial w}{\partial x} \equiv 0$$

Along \overline{ad} the symmetry conditions are

$$v = 0$$

$$\omega_\theta = 0$$

$$N_{\theta x} = 0; M_{\theta x} = 0$$

$$Q_\theta = 0$$

2.3 STRESSES IN SKIN

Once the stress resultants and couples are known, the corresponding maximum and minimum stress of an isotropic shell can be computed by the relations

$$\sigma_x = \frac{1}{h} \hat{N}_x \pm \frac{6}{h^2} \hat{M}_x \quad (2.11)$$

$$\sigma_\theta = \frac{1}{h} \hat{N}_\theta \pm \frac{6}{h^2} \hat{M}_\theta \quad (2.12)$$

This is based on the assumption of a linear stress variation through the thickness given as

$$\sigma_i = \bar{\sigma}_i + z\sigma_i^b \quad (2.13)$$

where $\bar{\sigma}_i$ is a membrane stress and $z\sigma_i^b$ is the stress due to bending.

Section 3
NUMERICAL ANALYSIS

The finite-difference method is used to solve the governing equations of a conical shell segment with fixed edges. The scheme in this numerical method of solution is to replace the continuous problem of a continuous coordinate system by one defined at a finite number of coordinate points. To accomplish this discretization, the continuous two dimensional (x, θ) domain of the conical shell is covered by a uniform rectangular net as shown in Fig. 7. Lattice points of this net which are within the domain \tilde{D}

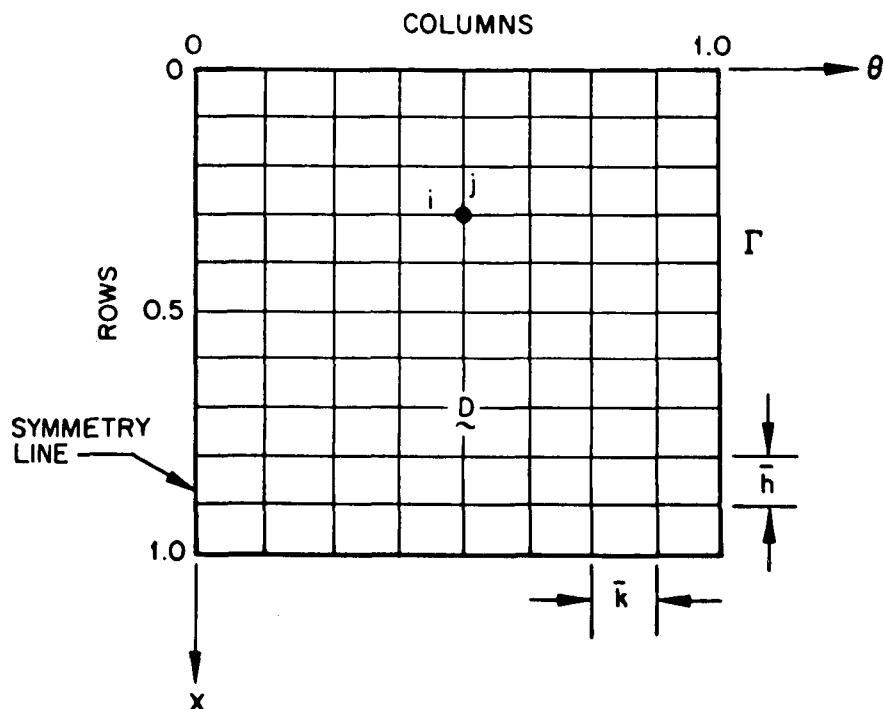


Fig. 7 Domain and Boundary of Conical Shell Segment

are called mesh points and lattice points on the boundary curve Γ are called boundary points. At these lattice points the dependent variables (u, v, w) of the governing differential equations are replaced by the discrete values of u_i^j, v_i^j, w_i^j . The subscript i of u_i^j denotes the row number and corresponds to the x -coordinate while the superscript j denotes the column number and corresponds to the θ -coordinate. In general, the boundary curve does not coincide with the net. However, in the problem under consideration, this complication does not exist.

The difference equations which are a set of algebraic relations representing the governing equations and boundary conditions are formed by first approximating the derivatives at a given point by a function of the variable at neighboring points. These functions replace the derivatives of the governing equations. Thus, at each mesh point three algebraic equations can be written in terms of neighboring points. When the boundary conditions are accounted for in these equations the resulting set of simultaneous algebraic equations

$$\tilde{A}\tilde{X} = \tilde{B}$$

replaces the continuous problem. The solution of this set of algebraic equations can be accomplished by methods described in Vol. I.

3.1 APPROXIMATION OF DERIVATIVES

To transform the governing equations to difference form the derivatives of u, v, w are expressed in terms of their values at neighboring mesh points. These derivatives are determined by a Taylor series approximation* for a rectangular net and are given by the following equations:

*"Investigation of Juncture Stress Fields in Multicellular Shell Structures," by E. Y. W. Tsui, F. A. Brogan, J. M. Massard, P. Stern, and C. E. Stuhlman, Technical Report M-03-63-1, Lockheed Missiles & Space Company, Sunnyvale, Calif., Feb 1964 - NASA CR-61050.

$$f_{,x} = 1/2\bar{h}(f_1^0 - f_{-1}^0) \quad (3.1a)$$

$$f_{,xx} = 1/\bar{h}^2(f_1^0 - 2f_0^0 + f_{-1}^0) \quad (3.1b)$$

$$f_{,xxx} = 1/2\bar{h}^3(f_2^0 - 2f_1^0 + 2f_{-1}^0 - f_{-2}^0) \quad (3.1c)$$

$$f_{,xxxx} = 1/\bar{h}^4(f_2^0 - 4f_1^0 + 6f_0^0 - 4f_{-1}^0 + f_{-2}^0) \quad (3.1d)$$

$$f_{,\theta} = 1/2\bar{k}(f_0^1 - f_0^{-1}) \quad (3.1e)$$

$$f_{,\theta\ell} = 1/\bar{k}^2(f_0^1 - 2f_0^0 + f_0^{-1}) \quad (3.1f)$$

$$f_{,\theta\partial\theta} = 1/2\bar{k}^3(f_0^2 - 2f_0^1 + 2f_0^{-1} - f_0^{-2}) \quad (3.1g)$$

$$f_{,\theta\theta\theta} = 1/\bar{k}^4(f_0^2 - 4f_0^1 + 6f_0^0 - 4f_0^{-1} + f_0^{-2}) \quad (3.1h)$$

$$f_{,x\theta} = 1/4\bar{h}\bar{k}(f_1^1 - f_{-1}^1 - f_1^{-1} + f_{-1}^{-1}) \quad (3.1i)$$

$$f_{,xx\theta} = 1/2\bar{h}^2\bar{k}(-2f_0^1 + 2f_0^{-1} + f_1^1 + f_{-1}^1 - f_1^{-1} - f_{-1}^{-1}) \quad (3.1j)$$

$$f_{,x\theta\theta} = 1/2\bar{h}\bar{k}^2(-2f_1^0 + 2f_{-1}^0 + f_1^1 + f_{-1}^{-1} - f_{-1}^1 - f_{-1}^{-1}) \quad (3.1k)$$

$$f_{,xx\theta\theta} = 1/\bar{h}^2\bar{k}^2(-2f_1^0 - 2f_{-1}^0 - 2f_0^1 - 2f_0^{-1} + f_1^1 + f_{-1}^1 + f_1^{-1} + f_{-1}^{-1} + 4f_0^0) \quad (3.1l)$$

Lower order approximations to be used as noted

$$v_{,\theta\theta\theta} = 1/\bar{k}^3 \left[v_0^1 - 3v_0^0 + 3v_0^{-1} - v_0^{-2} \right] \quad (3.1m)$$

3.2 DIFFERENCE EQUATIONS

The formation of the difference equations is effected in a straightforward manner by substituting the appropriate expressions of Eqs. (3.1) into the governing equations [Eqs. (2.8)]. A complication arises when the equations are written at each mesh point and the boundary conditions are included in the appropriate equations; i.e., it is not possible to obtain a sufficient number of equations as unknowns. The application of central difference approximations requires that low-order approximations be used near the boundary so that this problem will not occur. It is noted that Eq. (2.8c) contains a third derivative of v with respect to θ . The third derivative as given by Eq. (3.1g) is in terms of five points hence is a higher order approximation (only four points are necessary for a third derivative). It was decided to incorporate the four point derivative [Eq. (3.1m) for $v_{\theta\theta\theta}$] throughout. After these substitutions the governing equations in difference form at a point o, o are as follows:

$$A_1 u_1^o + A_2 u_{-1}^o + A_3(u_o^1 + u_o^{-1}) + A_4 u_o^o + A_5(v_1^1 - v_{-1}^1 - v_1^{-1} + v_{-1}^{-1}) \\ + A_6(v_o^1 - v_o^{-1}) + A_7(w_1^o - w_{-1}^o) + A_8 w_o^o = A_o^o \quad (3.2a)$$

$$B_1(u_1^1 - u_{-1}^1 - u_1^{-1} + u_{-1}^{-1}) + B_2(u_o^1 - u_o^{-1}) + B_3 v_1^o + B_4 v_{-1}^o \\ + B_5(v_o^1 + v_o^{-1}) + B_6 v_o^o + B_7(w_o^1 - w_o^{-1}) + B_8(w_1^1 - w_1^{-1}) \\ + B_9(w_{-1}^1 - w_{-1}^{-1}) + B_{10}(w_o^2 - w_o^{-2}) = B_o^o \quad (3.2b)$$

$$C_1(u_1^o - u_{-1}^o) + C_2 u_o^o + C_3 v_o^1 + C_4 v_o^{-1} + C_5(v_1^1 - v_1^{-1}) \\ + C_6(v_{-1}^1 - v_{-1}^{-1}) + C_7 v_o^{-2} + C_8 v_o^o + C_9 w_2^o + C_{10} w_{-2}^o \\ + C_{11}(w_o^2 + w_o^{-2}) + C_{12} w_1^o + C_{13} w_{-1}^o + C_{14}(w_o^1 + w_1^{-1}) \\ C_{15}(w_1^1 + 10_1^{-1}) + C_{16}(w_{-1}^1 + w_{-1}^{-1}) + C_{17} w_o^o = C_o^o \quad (3.2c)$$

when

$$A_1 = a_1/\bar{h}^2 + a_3/2\bar{h}$$

$$A_2 = a_1/\bar{h}^2 - a_3/2\bar{h}$$

$$A_3 = a_2/\bar{k}^2$$

$$A_4 = -[A_1 + A_2] - 2A_3 + a_4$$

$$A_5 = a_5/4\bar{h}\bar{k}$$

$$A_6 = a_6/2\bar{k}$$

$$A_7 = a_7/2\bar{h}$$

$$A_8 = a_8$$

$$A_o^o = A$$

$$B_1 = b_1/4\bar{h}\bar{k}$$

$$B_2 = b_2/2\bar{k}$$

$$B_3 = b_3/\bar{h}^2 + b_5/2\bar{h}$$

$$B_4 = b_3/\bar{h}^2 - b_5/2\bar{h}$$

$$B_5 = b_4/\bar{k}^2$$

$$B_6 = -[B_3 + B_4] - 2B_5 + b_6$$

$$B_7 = -b_7/\bar{h}^2\bar{k} - b_8/\bar{k}^3 + b_{10}/2\bar{k}$$

$$B_8 = b_7/2\bar{h}^2\bar{k} + b_9/4\bar{h}\bar{k}$$

$$B_9 = b_7/2\bar{h}^2\bar{k} - b_9/4\bar{h}\bar{k}$$

$$B_{10} = b_8/2\bar{k}^3$$

$$B_0^0 = B$$

$$C_1 = c_1/2\bar{h}$$

$$C_2 = c_2$$

$$C_3 = -c_3/\bar{h}^2\bar{k} + c_4/\bar{k}^3 + c_6/2\bar{k}$$

$$C_4 = c_3/\bar{h}^2\bar{k} + 3c_4/\bar{k}^3 - c_6/2\bar{k}$$

$$C_5 = c_3/2\bar{h}^2\bar{k} + c_5/4\bar{h}\bar{k}$$

$$C_6 = c_3/2\bar{h}^2\bar{k} - c_5/4\bar{h}\bar{k}$$

$$C_7 = -c_4/\bar{k}^3$$

$$C_8 = -3c_4/\bar{k}^3$$

$$C_9 = c_7/\bar{h}^4 + c_{10}/2\bar{h}^3$$

$$C_{10} = c_7/\bar{h}^4 - c_{10}/2\bar{h}^3$$

$$C_{11} = c_9/\bar{k}^4$$

$$C_{12} = -4c_7/\bar{h}^4 - 2c_8/\bar{h}^2\bar{k}^2 - c_{10}/\bar{h}^3 - c_{11}/\bar{h}\bar{k}^2 + c_{12}/\bar{h}^2 + c_{14}/2\bar{h}$$

$$C_{13} = -4c_7/\bar{h}^4 - 2c_8/\bar{h}^2\bar{k}^2 + c_{10}/\bar{h}^3 + c_{11}/\bar{h}\bar{k}^2 + c_{12}/\bar{h}^2 - c_{14}/2\bar{h}$$

$$C_{14} = -2c_8/\bar{h}^2\bar{k}^2 - 4c_9/\bar{k}^4 + c_{13}/\bar{k}^2$$

$$C_{15} = c_8/\bar{h}^2\bar{k}^2 + c_{11}/2\bar{h}\bar{k}^2$$

$$C_{16} = c_8/\bar{h}^2\bar{k}^2 - c_{11}/2\bar{h}\bar{k}^2$$

$$C_{17} = 6c_7/\bar{h}^4 + 4c_8/\bar{h}^2\bar{k}^2 + 6c_9/\bar{k}^4 - 2c_{12}/\bar{h}^2 - 2c_{13}/\bar{k}^2 + c_{15}$$

$$C_o^o = C$$

The complete set of difference equations are obtained by writing these equations at each mesh point. Along lines of symmetry only two equations are necessary since one of the variables will be zero. After the incorporation of fixed edge boundary conditions, a sufficient number of equations for unknowns yields a set of simultaneous algebraic equations which are written in matrix form as

$$\tilde{A}\tilde{X} = \tilde{B}$$

Unless care is exercised in ordering the equations and unknowns, the square matrix \tilde{A} can be full. From the aspect of solving a large number of equations (Vol. I), the ordering is important. To establish an insight into the idea of the ordering employed, it is noticed from the difference expressions [Eqs. (3.1)] that the highest derivatives are in terms of at most two rows "above;" two rows "below;" two columns to the "left," and two columns to the "right" of a given meshpoint. If all the equations for a given column were written and stored in submatrix form, the unknowns would involve two columns to the "right" and "left." Thus, any column would involve, at most, five submatrices. The matrix A is accordingly partitioned in the manner shown below, where m is the number of columns in the finite difference net.

$$\tilde{A} = \begin{bmatrix} E_1 F_1 G_1 \dots & 0 \\ D_2 E_2 F_2 G_2 & \\ C_3 D_3 E_3 F_3 G_3 0 & \\ \vdots & G_{n-2} \\ & F_{m-1} \\ C_m D_m E_m & \end{bmatrix}$$

This matrix \tilde{A} is obtained by writing Eqs. (3.1) in \tilde{D} and not on the boundary Γ . The boundary and symmetry conditions have been used to eliminate certain equations. Fixed-edge boundary conditions are well-suited for this formulation, since they do not require complex algebraic expressions. Specifically, if Eqs. (3.1) are written one column from the boundary, then the submatrix F_m is zero ($u = v = w = 0$) and the submatrix G_m contains only w terms which are reflected into E_m due to the boundary condition. Along a symmetry line all terms are either reflected with the same or opposite sign. This fact accounts for the missing C_1 and D_1 matrices. Similar alterations are made in each matrix to account for boundary and symmetry conditions.

For a conical shell, the solution in \tilde{D} is not uniform; at the boundary ($x = 0, 1$) the variation of the dependent variables occurs in a small interval. Such boundary behavior is characteristic of shell-type problems. For a conical shell, this behavior occurs only in the x -direction. To reveal the solution in sufficient detail in this region requires a small mesh spacing which may be accomplished by grading without destroying the form of A . An explanation of grading was given in Vol. II, Sec. 3.3

Section 4

DIGITAL PROGRAM

4.1 GENERAL DESCRIPTION

The present program provides solutions for fixed-edge conical shell panels under loads and changes of temperature. The method of solution consists basically in obtaining the displacement components u , v , and w at various discrete stations of the structure by finite-difference approximation (see Secs. 2 and 3). The corresponding strains and stresses may then be computed.

The program is designed to compute the fixed-edge forces due to intermediate loads or thermal gradient. However, displacements, strains, and stresses in the loaded region are also evaluated simultaneously. The following program options are available:

- Finite-difference mesh
 - (a) Uniform spacing
 - (b) Graded spacing in the x-direction
- Loading conditions
 - (a) Uniform normal pressure
 - (b) Gravitational loading
 - (c) Linear temperature gradient through the skin thickness

There are restrictions on the geometrical dimensions of panels. However, the accuracy with which the basic differential equations are approximated may vary for different configurations of the conical shell.

The finite-difference mesh network is specified completely by prescribing the number of rows and columns exclusive of the boundaries, together with the grading options which have been chosen. Rows in the finite-difference mesh are "parallel" to the

θ -axis, and columns correspond to generators of the cone. The number of rows may vary from 4 to 24 and the number of columns from 4 to 80. Thus, a maximum of 5760 unknowns can be solved. Greater accuracy near the boundaries can often be obtained by selecting grading. By this means, it is possible to use a mesh spacing at the boundary as little as 1/32 of that at the middle portion of the panel.

There are certain restrictions on the use of the grading option. When such an option is used, a separate input card is required to specify a mesh spacing exponent MM(J) for each row J. The finite-difference equations are written along Row J, then the mesh spacing $XH/2^{**MM(J)}$ is used. This distance must be the least of the two distances from Row J to the row above and the row below. XH is the basic input mesh spacing along the x-direction. For any Row J, MM(J) and MM(J + 1) must not differ by more than 1. Also, three consecutive rows cannot have three distinct exponents. MM(J) may vary from 0 to 5.

The description of symbols and input data are shown in Tables 1 and 2. Figure 8 shows the flow diagram of this program.

Table 1
DESCRIPTION OF SYMBOLS

Symbol	Description
RECORD	Hollerith information describing problem
I _φ PT1	0 Uniform mesh spacing
	1 Graded mesh spacing in x-direction
I _φ PT2	0 Uniform normal pressure
	1 Gravitational loading
I _φ PT3	2 Linear temperature gradient through the skin thickness
	0 Omit shell strains
I _φ PT4	1 Print shell straining
	0 Not last case with plots
	1 Last case with plots

Table 1 (cont'd)

Symbol	Description
R _φ W	Number of rows in the finite-difference mesh
C _φ L	Number of columns in the finite-difference mesh
XH	Basic distance between rows in the mesh
XK	Basic distance between columns in the mesh
ZNU	Poisson's ratio
THC	Half angle of segment (see Fig. 3)
HB _φ	Nondimensional reference thickness (\hat{h}_o/\hat{X}_L)
H1	Rate of change of thickness in x
X _φ XL	Nondimensional distance (see Fig. 3) ($=\hat{x}_\theta/\hat{X}_L$)
PH3	Half cone angle
PH2	Angle defining orientation of cone axis relative to gravitational force (see Fig. 3)
TE	External temperature
TI	Internal temperature
T _φ	Ambient temperature for zero stress
φC	Coefficient of thermal expansion
MM(J), J = 1, R _φ W	Grading mesh constants; mesh spacing used for difference equations on Row J is equal to XH/2.*MM(J)
MM(31)	Number of rows to be plotted
MM(32)	Four row numbers for which plot output is desired
MM(33)	(U, V, W, N _X , M _X , N _θ , M _θ)
MM(34)	
MM(35)	
CILBL(I, 1), I = 1, 6	Curve labels appearing on the plot output to identify the rows selected CILBL(I, 1) corresponds to MM(32); etc.
CILBL(I, 2), I = 1, 6	
CILBL(I, 3), I = 1, 6	
CILBL(I, 4), I = 1, 6	

Table 2
INPUT DATA SEQUENCE AND FORMAT

Card	FORTRAN Symbol	Format
1	RECORD	72H
2	$I_\phi PT1, I_\phi PT2, I_\phi PT3$	3I1
3	$R_\phi W, C_\phi L, XH, XK$	3E12.8
4	ZNU, THC, HB ϕ , H1, X ϕ XL, PH3	6E12.8
5	PH2	E12.8
6 ^(a)	TE, TI, T ϕ , ϕ C	4E12.8
7 ^(b)	MM(J), J = 1, R ϕ W	35I2
8	MM(J), J = 31, 35	5I2
9 ^(c)	CILBL(I, 1), I = 1, 6	6A6
10 ^(c)	CILBL(I, 2), I = 1, 6	6A6
11 ^(c)	CILBL(I, 3), I = 1, 6	6A6
12 ^(c)	CILBL(I, 4), I = 1, 6	6A6

- (a) Omitted unless $I_\phi PT2 = 2$.
- (b) Omitted unless $I_\phi PT1 = 1$.
- (c) Omitted if MM(31) = 0.

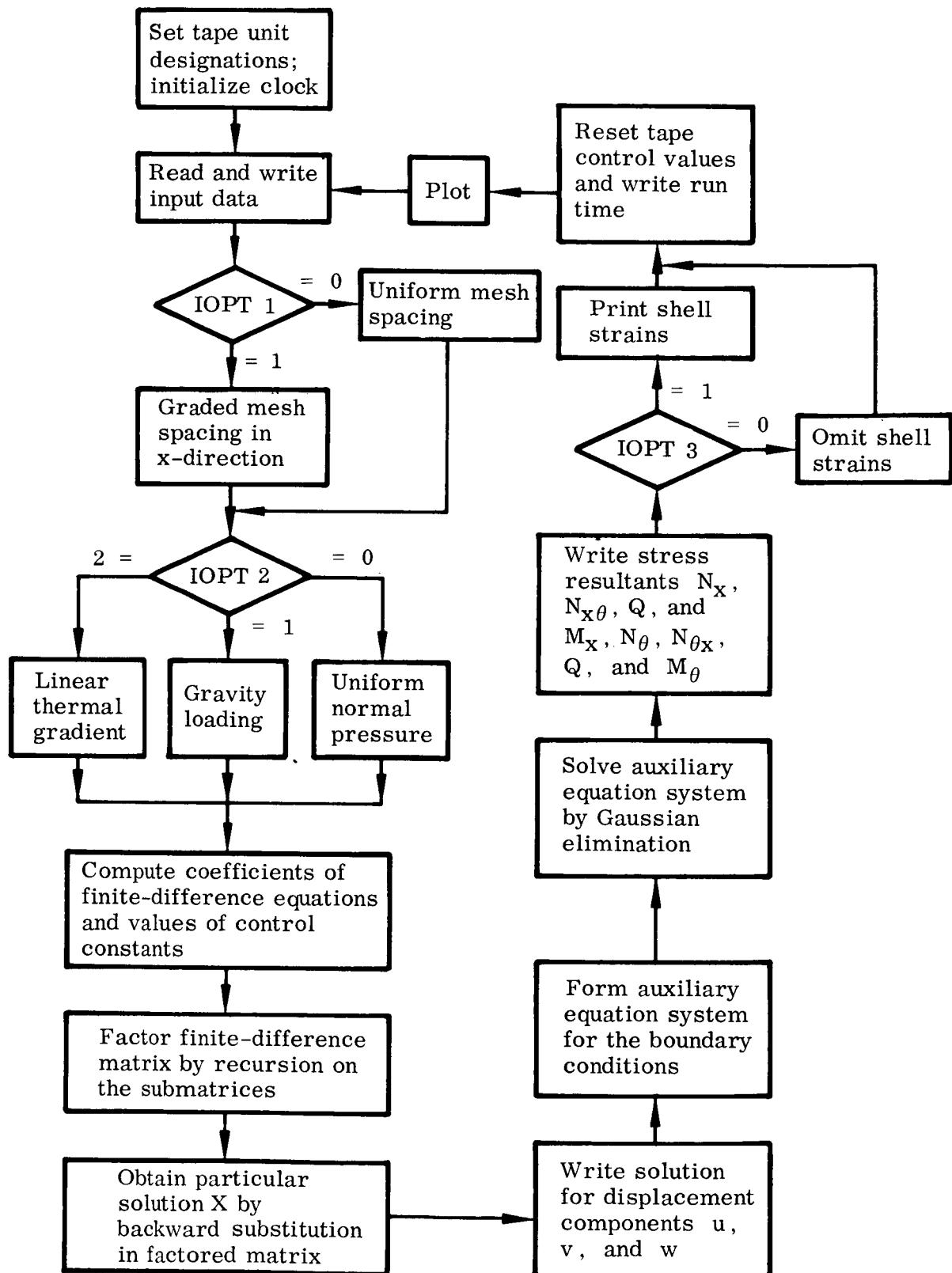
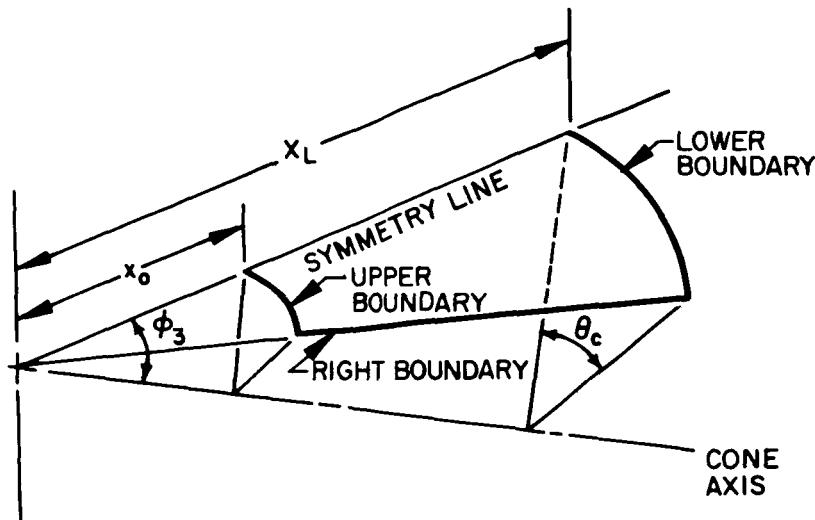


Fig. 8 Flow Chart

4.2 NUMERICAL EXAMPLE

The analysis of the conical panel shown in Fig. 9 will serve as an example to illustrate input data, format, and the type of information that can be obtained through use of the program described in this volume.



$$\begin{aligned}
 \theta_c &= \text{THC} = 0.61 \text{ radian} \\
 h_o/X_L &= \text{HB}\phi = 0.0045 \\
 \phi_3 &= \text{PH3} = 0.497 \text{ radian} \\
 x_o/X_L &= X\phi_{XL} = 0.3 \\
 h_1 &= H_1 = 0.0
 \end{aligned}$$

Fig. 9 Conical Shell Panel for Example

The example is for the loading option of uniform normal pressure ($p_z = \text{constant}$) . Grading is used in the x-coordinate so as to obtain a reasonable solution with the present restrictions of the computer program (24 rows, 80 columns). The actual mesh spacing which yields a solution of desired accuracy must be obtained by exploratory runs using different number of rows and columns. Such runs were made with the given geometry. It was found that 20 rows and 20 columns were required to obtain satisfactory results in both displacements and stress resultants. More accurate results can be obtained by use of an even finer mesh spacing.

Values of input quantities for the 20 by 20 case are given in Table 3 and a listing of the corresponding input data cards is presented in Table 4. For convenience, the x-coordinate corresponding to the row number follows:

$x = 0.3$	— Row 21	$x = 0.7$	— Row 10
$x = 0.30625$	— Row 20	$x = 0.8$	— Row 9
$x = 0.31250$	— Row 19	$x = 0.85$	— Row 8
$x = 0.325$	— Row 18	$x = 0.9$	— Row 7
$x = 0.3375$	— Row 17	$x = 0.925$	— Row 6
$x = 0.35$	— Row 16	$x = 0.95$	— Row 5
$x = 0.375$	— Row 15	$x = 0.9625$	— Row 4
$x = 0.4$	— Row 14	$x = 0.975$	— Row 3
$x = 0.45$	— Row 13	$x = 0.9875$	— Row 2
$x = 0.5$	— Row 12	$x = 0.99375$	— Row 1
$x = 0.6$	— Row 11	$x = 1.0$	— Row 0

Results from the computer program are in the form of printed digital values and selected plots. Sample printed output given in Table 5 presents displacement components (u, v, w) , stress resultants ($N_x, N_\theta, N_{\theta x}, N_{x\theta}, M_x, M_\theta, M_{x\theta}, Q_x, Q_\theta$) , and boundary stress resultants (N_{tan}, N_{norm}, Q, M) . [Note that these quantities are in nondimensional form as defined in Sec. 2.] Plotted output includes displacement components (u, v, w) and stress resultants ($N_x, N_\theta, M_x, M_\theta$) along Rows 1, 2, 10, and 16 and boundary stress resultants (N_{tan}, N_{norm}, Q, M) along the boundary curve. This plotted output is shown in Figs. 10a through o.

Table 3
INPUT VALUES FOR THE EXAMPLE

Symbol	Value	Symbol	Value
I ϕ PT1	1	MM(7)	2
I ϕ PT2	0	MM(8)	1
I ϕ PT3	0	(9)	1
I ϕ PT4	1	(10)	0
R ϕ W	20.0	(11)	0
C ϕ L	20.0	(12)	1
XH	0.1	(13)	1
XK	0.05	(14)	2
ZNU	0.3	(15)	2
		(16)	3
THC	0.61	(17)	3
HB ϕ	0.0045	(18)	3
H1	0	(19)	4
X ϕ XL	0.3	(20)	4
PH3	0.4974		
MM(1)	4	PH2, TE, TI, T ϕ , } MM(2)	4
MM(3)	3	T ϕ , ϕ C } MM(4)	3
MM(5)	3	MM(31)	04
MM(6)	2	MM(32)	01
		MM(33)	02
		MM(34)	10
		MM(35)	16
		CILBL(I, 1)I = 1, 6	x = 0.99375, Row 1
		CILBL(I, 2)I = 1, 6	x = 0.9875, Row 2
		CILBL(I, 3)I = 1, 6	x = 0.7, Row 10
		CILBL(I, 4)I = 1, 6	x = 0.35, Row 16

Table 4
INPUT DATA IN REQUIRED FORMAT

INPUT DATA		SEARCH NUMBER		PROGRAM		DATE NEEDS		PRIORITY		PAGE _____ OF _____	
ITEM NO.	ITEM NO.	ITEM NO.	ITEM NO.	ITEM NO.	ITEM NO.	ITEM NO.	ITEM NO.	ITEM NO.	ITEM NO.	ITEM NO.	ITEM NO.
EXAMPLE UNIFORM THICKNESS CONE UNDER NORMAL PRESSURE											
1 0 0 1											
2 0	+ 2	2	+ 2	1	+ 0	0 5	+ 0				
3	+ 0	6 1	+ 0	4 5	+ 0	2 0	+ 0	0 3	+ 0	4 9 7 4	+ 0
0 4 0 4 0 3 0 3 0 3 0 2 0 2 0 1 0 1 0 0 0 0 0 1 0 1 0 2 0 2 0 3 0 3 0 3 0 4 0 4											
OMIT	THIS	CARD									
OMIT	THIS	CARD									
0 4 0 1 0 2 1 0 1 6											
$x = 0$	9 9 3 3 7 5	ROW 1									
$x = 0$	9 8 7 5	ROW 2									
$x = 0$	7	ROW 0									
$x = 0$	3 5	ROW 16									
LOCKHEED MISSILES & SPACE COMPANY											

Table 5

EXAMPLE UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

CONE DISPLACEMENT COMPONENTS (U, V, W)

COL	ROW		U	V	W
5,	23		0.	0.	3.758916E 00
5,	22		7.908239E-02	7.785636E-02	7.579740E-01
5,	21	BOUNDARY	0.	0.	0.
5,	20		-3.362265E-02	-3.673874E-02	7.579740E-01
5,	19		-7.104976E-02	-8.186667E-02	2.304875E 00
5,	18		-1.615456E-01	-1.848906E-01	6.000734E 00
5,	17		-2.752391E-01	-2.967736E-01	9.196216E 00
5,	16		-3.948630E-01	-4.054488E-01	1.154391E 01
5,	15		-6.231503E-01	-6.061811E-01	1.514472E 01
5,	14		-8.159761E-01	-7.735714E-01	1.785936E 01
5,	13		-1.139539E 00	-1.066647E 00	2.299319E 01
5,	12		-1.375848E 00	-1.345499E 00	2.841883E 01
5,	11		-1.706683E 00	-1.873214E 00	4.012625E 01
5,	10		-1.760347E 00	-2.132267E 00	5.135078E 01
5,	9		-1.627839E 00	-1.779540E 00	5.982047E 01
5,	8		-1.545866E 00	-1.434067E 00	6.324532E 01
5,	7		-1.433594E 00	-9.807496E-01	6.121979E 01
5,	6		-1.322050E 00	-7.431383E-01	5.409486E 01
5,	5		-1.058156E 00	-5.001187E-01	3.748522E 01
5,	4		-8.731902E-01	-3.774183E-01	2.779011E 01
5,	3		-6.295027E-01	-2.532754E-01	1.671943E 01
5,	2		-3.282747E-01	-1.273256E-01	6.098203E 00
5,	1		-1.665396E-01	-6.389136E-02	1.878688E 00
5,	-0	BOUNDARY	0.	0.	0.
5,	-1		3.156418E-01	1.273210E-01	1.878688E 00
5,	-2		0.	0.	8.931297E 00

CONE STRESS RESULTANTS.

ROW	COL	NX	NTHETA	NXTTHETA	NTHETAX
9,	17	2.5156E 01	9.2013E 01	1.7981E 01	1.7955E 01
9,	18	2.5025E 01	9.1296E 01	2.0416E 01	2.0362E 01
9,	19	2.5184E 01	9.0449E 01	2.3062E 01	2.2993E 01
9,	20	2.5663E 01	8.9436E 01	2.5701E 01	2.5645E 01
9,	21	2.6824E 01	8.9414E 01	2.8034E 01	2.8034E 01
10,	1	2.6187E 01	8.4748E 01	6.9418E-09	0.
10,	2	2.6156E 01	8.4728E 01	8.6731E-01	8.7402E-01
10,	3	2.6062E 01	8.4670E 01	1.7268E 00	1.7401E 00
10,	4	2.5907E 01	8.4575E 01	2.5725E 00	2.5919E 00
10,	5	2.5693E 01	8.4448E 01	3.4014E 00	3.4263E 00

Table 5 (cont'd)

10,	6	2.5424E 01	8.4293E 01	4.2149E 00	4.2446E 00
10,	7	2.5106E 01	8.4117E 01	5.0197E 00	5.0529E 00
10,	8	2.4747E 01	8.3926E 01	5.8281E 00	5.8633E 00
10,	9	2.4358E 01	8.3724E 01	6.6573E 00	6.6924E 00
10,	10	2.3953E 01	8.3517E 01	7.5282E 00	7.5611E 00
10,	11	2.3551E 01	8.3306E 01	8.4639E 00	8.4922E 00
10,	12	2.3172E 01	8.3090E 01	9.4868E 00	9.5080E 00
10,	13	2.2840E 01	8.2867E 01	1.0615E 01	1.0627E 01
10,	14	2.2579E 01	8.2629E 01	1.1861E 01	1.1862E 01
10,	15	2.2412E 01	8.2366E 01	1.3227E 01	1.3216E 01
10,	16	2.2359E 01	8.2066E 01	1.4702E 01	1.4680E 01
10,	17	2.2432E 01	8.1714E 01	1.6265E 01	1.6233E 01
10,	18	2.2634E 01	8.1298E 01	1.7883E 01	1.7847E 01
10,	19	2.2957E 01	8.0806E 01	1.9518E 01	1.9485E 01
10,	20	2.3379E 01	8.0233E 01	2.1132E 01	2.1110E 01
10,	21	2.4042E 01	8.0139E 01	2.2614E 01	2.2614E 01
11,	1	2.0224E 01	7.2057E 01	-0.	0.
11,	2	2.0199E 01	7.2052E 01	4.9524E-01	5.0047E-01
11,	3	2.0124E 01	7.2038E 01	1.0045E 00	1.0146E 00
11,	4	2.0004E 01	7.2014E 01	1.5414E 00	1.5558E 00
11,	5	1.9845E 01	7.1981E 01	2.1190E 00	2.1368E 00
11,	6	1.9657E 01	7.1939E 01	2.7492E 00	2.7693E 00
11,	7	1.9450E 01	7.1888E 01	3.4425E 00	3.4634E 00
11,	8	1.9239E 01	7.1826E 01	4.2072E 00	4.2277E 00
11,	9	1.9036E 01	7.1752E 01	5.0492E 00	5.0678E 00
11,	10	1.8857E 01	7.1664E 01	5.9713E 00	5.9866E 00
11,	11	1.8715E 01	7.1560E 01	6.9729E 00	6.9838E 00
11,	12	1.8624E 01	7.1437E 01	8.0496E 00	8.0551E 00
11,	13	1.8595E 01	7.1289E 01	9.1934E 00	9.1930E 00
11,	14	1.8635E 01	7.1114E 01	1.0393E 01	1.0387E 01
11,	15	1.8749E 01	7.0907E 01	1.1634E 01	1.1622E 01

CONE STRESS RESULTANTS.

ROW	COL	MX	MTHETA	MXTHETA	QX	QTTHETA
9,	17	-1.3067E 03	-1.7220E 03	1.1719E 03	4.0291E 04	-3.2833E 05
9,	18	-2.4944E 03	-6.1771E 03	1.3981E 03	1.9941E 04	-4.2056E 05
9,	19	-3.9484E 03	-1.1815E 04	1.3710E 03	-1.2380E 04	-5.1920E 05
9,	20	-5.7424E 03	-1.8649E 04	9.5254E 02	-5.8796E 04	-6.2300E 05
9,	21	-7.9898E 03	-2.6633E 04	0.	-1.2065E 05	-6.9175E 05
10,	1	1.1689E 03	2.5163E 03	0.	-2.3825E 04	2.3404E-03
10,	2	1.1702E 03	2.5559E 03	-1.5545E 02	-2.3239E 04	6.0257E 03
10,	3	1.1733E 03	2.6707E 03	-3.0268E 02	-2.1485E 04	1.1361E 04
10,	4	1.1756E 03	2.8498E 03	-4.3355E 02	-1.8581E 04	1.5355E 04
10,	5	1.1732E 03	3.0752E 03	-5.4010E 02	-1.4565E 04	1.7381E 04

Table 5 (cont'd)

10,	6	1.1610E 03	3.3219E 03	-6.1474E 02	-9.5074E 03	1.6873E 04
10,	7	1.1329E 03	3.5591E 03	-6.5052E 02	-3.5279E 03	1.3349E 04
10,	8	1.0822E 03	3.7505E 03	-6.4163E 02	3.1883E 03	6.4118E 03
10,	9	1.0022E 03	3.8555E 03	-5.8391E 02	1.0371E 04	-4.2386E 03
10,	10	8.8631E 02	3.8300E 03	-4.7560E 02	1.7652E 04	-1.8807E 04
10,	11	7.2789E 02	3.6277E 03	-3.1818E 02	2.4551E 04	-3.7412E 04
10,	12	5.2057E 02	3.2009E 03	-1.1724E 02	3.0478E 04	-6.0104E 04
10,	13	2.5768E 02	2.5023E 03	1.1661E 02	3.4743E 04	-8.6895E 04
10,	14	-6.8351E 01	1.4851E 03	3.6698E 02	3.6582E 04	-1.1779E 05
10,	15	-4.6688E 02	1.0422E 02	6.1120E 02	3.5203E 04	-1.5285E 05
10,	16	-9.5029E 02	-1.6836E 03	8.2018E 02	2.9853E 04	-1.9218E 05
10,	17	-1.5353E 03	-3.9196E 03	9.5899E 02	1.9903E 04	-2.3606E 05
10,	18	-2.2442E 03	-6.6438E 03	9.8802E 02	4.9503E 03	-2.8490E 05
10,	19	-3.1064E 03	-9.8960E 03	8.6509E 02	-1.5078E 04	-3.3928E 05
10,	20	-4.1587E 03	-1.3717E 04	5.4839E 02	-3.9826E 04	-4.0000E 05
10,	21	-5.4454E 03	-1.8151E 04	1.2799E-06	-6.8451E 04	-4.3799E 05
11,	1	1.4361E 03	4.2899E 03	0.	-8.8557E 03	-0.
11,	2	1.4258E 03	4.2791E 03	-4.5114E 01	-8.5238E 03	-3.7656E 03
11,	3	1.3948E 03	4.2454E 03	-8.5470E 01	-7.5458E 03	-7.7640E 03
11,	4	1.3432E 03	4.1847E 03	-1.1657E 02	-5.9717E 03	-1.2209E 04
11,	5	1.2712E 03	4.0907E 03	-1.3443E 02	-3.8839E 03	-1.7316E 04
11,	6	1.1788E 03	3.9546E 03	-1.3582E 02	-1.3947E 03	-2.3287E 04
11,	7	1.0662E 03	3.7654E 03	-1.1849E 02	1.3575E 03	-3.0312E 04
11,	8	9.3319E 02	3.5103E 03	-8.1380E 01	4.2133E 03	-3.8570E 04
11,	9	7.7926E 02	3.1749E 03	-2.4808E 01	6.9964E 03	-4.8237E 04
11,	10	6.0344E 02	2.7433E 03	4.9416E 01	9.5211E 03	-5.9500E 04
11,	11	4.0397E 02	2.1978E 03	1.3789E 02	1.1598E 04	-7.2562E 04
11,	12	1.7810E 02	1.5198E 03	2.3556E 02	1.3041E 04	-8.7646E 04
11,	13	-7.8204E 01	6.8888E 02	3.3579E 02	1.3671E 04	-1.0502E 05
11,	14	-3.7064E 02	-3.1684E 02	4.3039E 02	1.3324E 04	-1.2500E 05
11,	15	-7.0682E 02	-1.5213E 03	5.0974E 02	1.1851E 04	-1.4796E 05

BOUNDARY STRESS RESULTANTS.

ROW	COL	NTAN	NNORM	Q	M	RBAR
21,	1	0.	-1.0596E 01	-2.9098E 06	-4.0056E 04	
21,	2	-2.2565E 00	-1.0496E 01	-2.9094E 06	-3.9980E 04	
21,	3	-4.4845E 00	-1.0197E 01	-2.9012E 06	-3.9751E 04	
21,	4	-6.6547E 00	-9.7016E 00	-2.8850E 06	-3.9363E 04	
21,	5	-8.7367E 00	-9.0164E 00	-2.8603E 06	-3.8808E 04	
21,	6	-1.0698E 01	-8.1488E 00	-2.8265E 06	-3.8074E 04	
21,	7	-1.2506E 01	-7.1095E 00	-2.7826E 06	-3.7146E 04	
21,	8	-1.4121E 01	-5.9128E 00	-2.7275E 06	-3.6006E 04	
21,	9	-1.5506E 01	-4.5769E 00	-2.6598E 06	-3.4633E 04	

Table 5 (cont'd)

21, 10	-1.6619E 01	-3.1245E 00	-2.5775E 06	-3.3005E 04
21, 11	-1.7417E 01	-1.5845E 00	-2.4785E 06	-3.1099E 04
21, 12	-1.7854E 01	7.0692E-03	-2.3600E 06	-2.8891E 04
21, 13	-1.7888E 01	1.6052E 00	-2.2183E 06	-2.6359E 04
21, 14	-1.7479E 01	3.1537E 00	-2.0490E 06	-2.3486E 04
21, 15	-1.6595E 01	4.5816E 00	-1.8464E 06	-2.0265E 04
21, 16	-1.5216E 01	5.7983E 00	-1.6038E 06	-1.6705E 04
21, 17	-1.3340E 01	6.6849E 00	-1.3151E 06	-1.2855E 04
21, 18	-1.0983E 01	7.0734E 00	-9.7857E 05	-8.8384E 03
21, 19	-8.1504E 00	6.6906E 00	-6.0671E 05	-4.9210E 03
21, 20	-4.7183E 00	4.9486E 00	-2.4658E 05	-1.6413E 03
21, 21	0.	0.	-3.8966E 03	0.
21, 21	-0.	0.	-0.	-0.
20, 21	7.0532E 00	6.5892E 00	-3.6001E 05	-3.1882E 03
19, 21	9.8552E 00	1.0971E 01	-8.0010E 05	-7.8935E 03
18, 21	1.1138E 01	1.9897E 01	-1.3462E 06	-1.6005E 04
17, 21	8.6463E 00	2.6894E 01	-1.3333E 06	-1.9038E 04
16, 21	5.0127E 00	3.2014E 01	-1.1151E 06	-1.8925E 04
15, 21	-1.4733E 00	3.9325E 01	-7.3631E 05	-1.6822E 04
14, 21	-6.3702E 00	4.3948E 01	-5.4809E 05	-1.5180E 04
13, 21	-1.2052E 01	5.0858E 01	-4.1492E 05	-1.3857E 04
12, 21	-1.4997E 01	5.7343E 01	-3.6144E 05	-1.3630E 04
11, 21	-1.9099E 01	6.9142E 01	-3.5116E 05	-1.4595E 04
10, 21	-2.2614E 01	8.0139E 01	-4.3799E 05	-1.8151E 04
9, 21	-2.8034E 01	8.9414E 01	-6.9175E 05	-2.6633E 04
8, 21	-3.4647E 01	9.1573E 01	-1.0135E 06	-3.4536E 04
7, 21	-4.3017E 01	8.4685E 01	-1.7166E 06	-4.6419E 04
6, 21	-4.7532E 01	7.5248E 01	-2.0057E 06	-4.8390E 04
5, 21	-4.5864E 01	5.7185E 01	-1.9549E 06	-4.1030E 04
4, 21	-4.2373E 01	4.7141E 01	-1.7552E 06	-3.4346E 04
3, 21	-3.5019E 01	3.5465E 01	-1.2468E 06	-2.2976E 04
2, 21	-2.1646E 01	2.1399E 01	-4.8861E 05	-8.7247E 03
1, 21	-1.2557E 01	1.2889E 01	-1.6640E 05	-2.8608E 03
0, 21	-0.	0.	-0.	-0.
0, 21	-0.	0.	-0.	-0.

BOUNDARY STRESS RESULTANTS.

ROW	COL	NTAN	NNORM	Q	M	RBAR
0, 21	0.	0.		-1.9484E 03	0.	
0, 20	3.5412E 01	2.6613E 01		-8.4219E 05	-1.5445E 04	
0, 19	5.0030E 01	3.5398E 01		-2.1986E 06	-3.5862E 04	
0, 18	5.7898E 01	3.9101E 01		-3.3425E 06	-5.3899E 04	
0, 17	6.1534E 01	4.0342E 01		-4.2128E 06	-6.8135E 04	
0, 16	6.2129E 01	4.0393E 01		-4.8500E 06	-7.8740E 04	

Table 5 (concl'd)

0, 15	6.0542E 01	3.9941E 01	-5.3021E 06	-8.6313E 04
0, 14	5.7438E 01	3.9349E 01	-5.6120E 06	-9.1500E 04
0, 13	5.3330E 01	3.8800E 01	-5.8148E 06	-9.4874E 04
0, 12	4.8615E 01	3.8376E 01	-5.9385E 06	-9.6903E 04
0, 11	4.3590E 01	3.8102E 01	-6.0046E 06	-9.7959E 04
0, 10	3.8473E 01	3.7973E 01	-6.0301E 06	-9.8332E 04
0, 9	3.3417E 01	3.7966E 01	-6.0279E 06	-9.8245E 04
0, 8	2.8520E 01	3.8053E 01	-6.0079E 06	-9.7870E 04
0, 7	2.3840E 01	3.8203E 01	-5.9780E 06	-9.7340E 04
0, 6	1.9398E 01	3.8386E 01	-5.9438E 06	-9.6755E 04
0, 5	1.5190E 01	3.8575E 01	-5.9100E 06	-9.6189E 04
0, 4	1.1192E 01	3.8746E 01	-5.8796E 06	-9.5698E 04
0, 3	7.3619E 00	3.8881E 01	-5.8553E 06	-9.5321E 04
0, 2	3.6506E 00	3.8968E 01	-5.8385E 06	-9.5085E 04
0, 1	0.	3.8998E 01	-5.8303E 06	-9.5005E 04

CASE NR 1 COMPLETED IN 10.700 MINUTES.

PLOT CALLED

PLOTTING COMPLETED

EXAMPLE UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

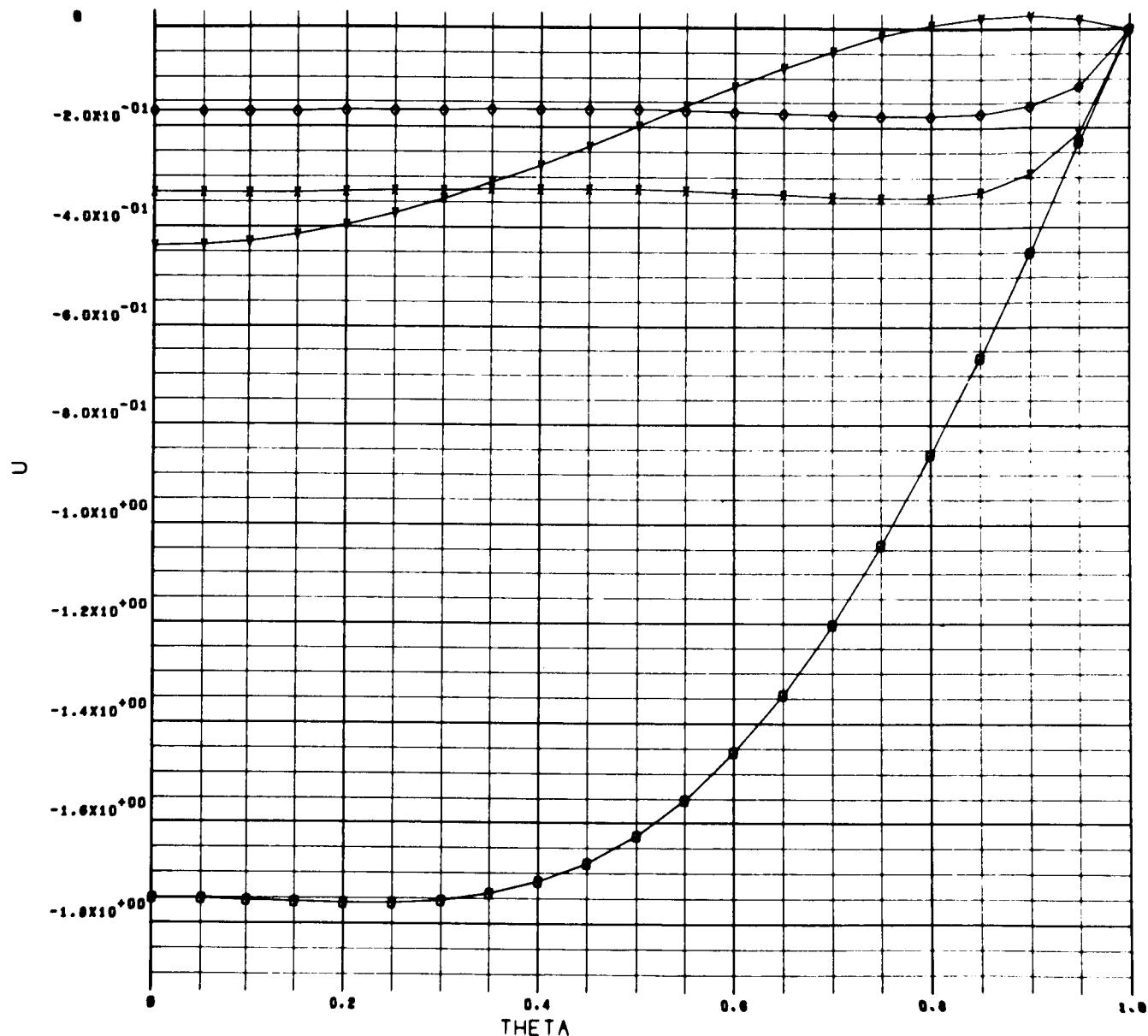
*\$F7
001 000

O X=0.99375 ,ROW 1

X X=0.9875 ,ROW 2

O X=0.7 ,ROW 10

Y X=0.35 ,ROW 16



a - Cone Displacement Components

Fig. 10 Output Plot for the Example: Uniform Thickness Cone Under Uniform Normal Pressure

EXAMPLE UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

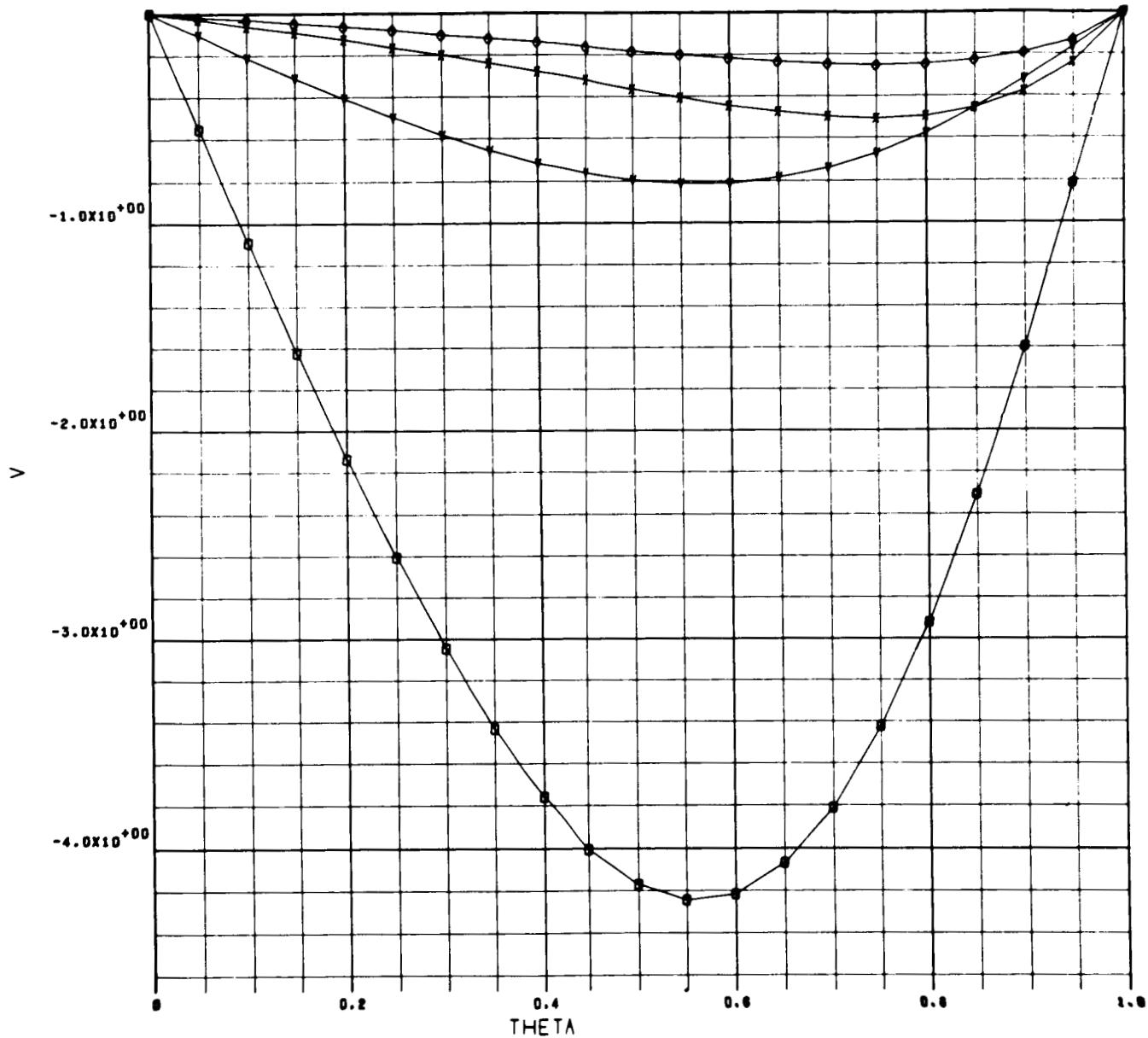
***FF7
002 000

G X=0.99375, ROW 1

G X=0.7 ,ROW 10

X X=0.9875 ,ROW 2

Y X=0.35 ,ROW 16



b - Cone Displacement Components

EXAMPLE UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

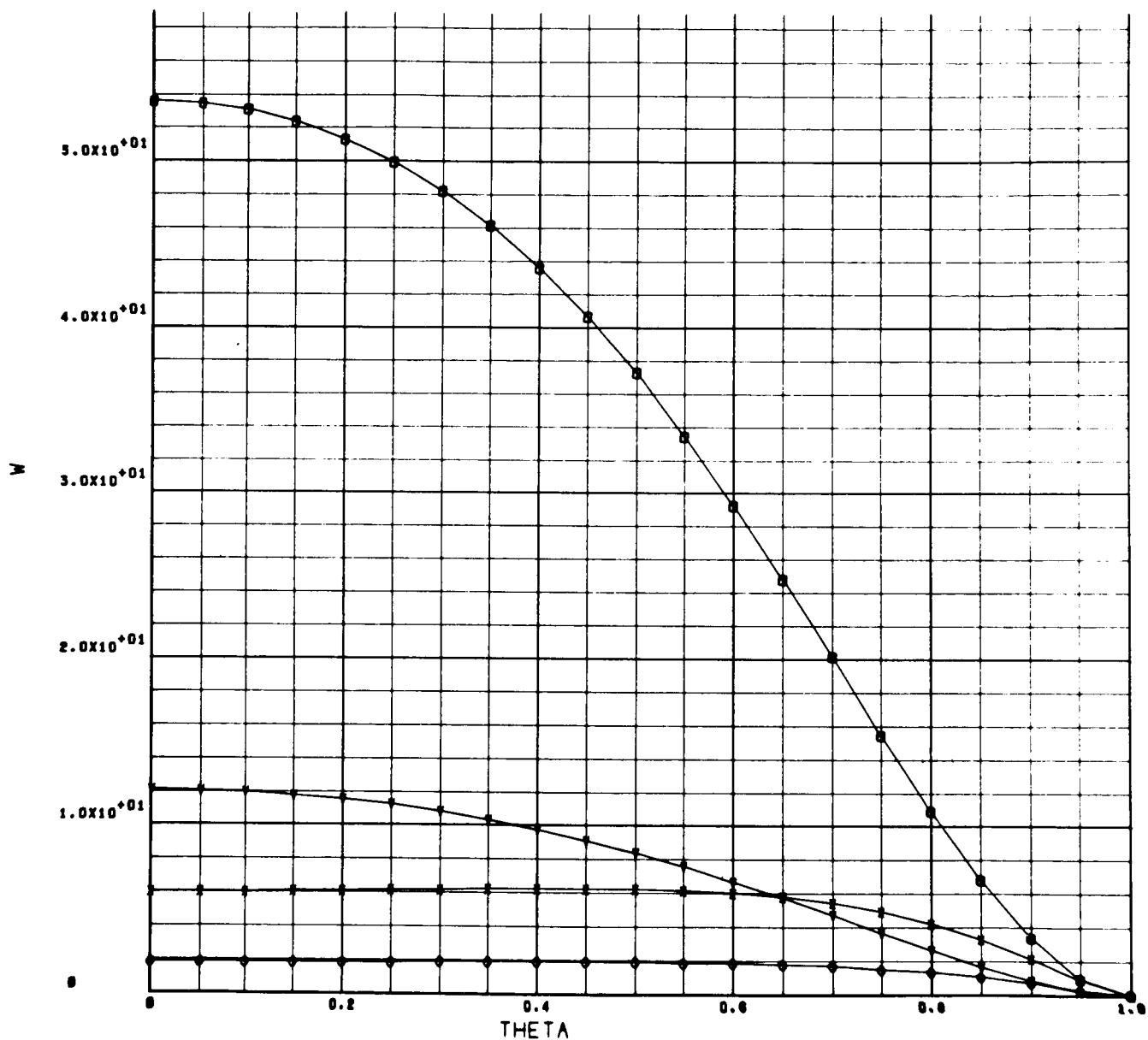
+8/F7
003 000

G X=0.99375, ROW 1

G X=0.7 ,ROW 10

X X=0.9875 ,ROW 2

Y X=0.35 ,ROW 16



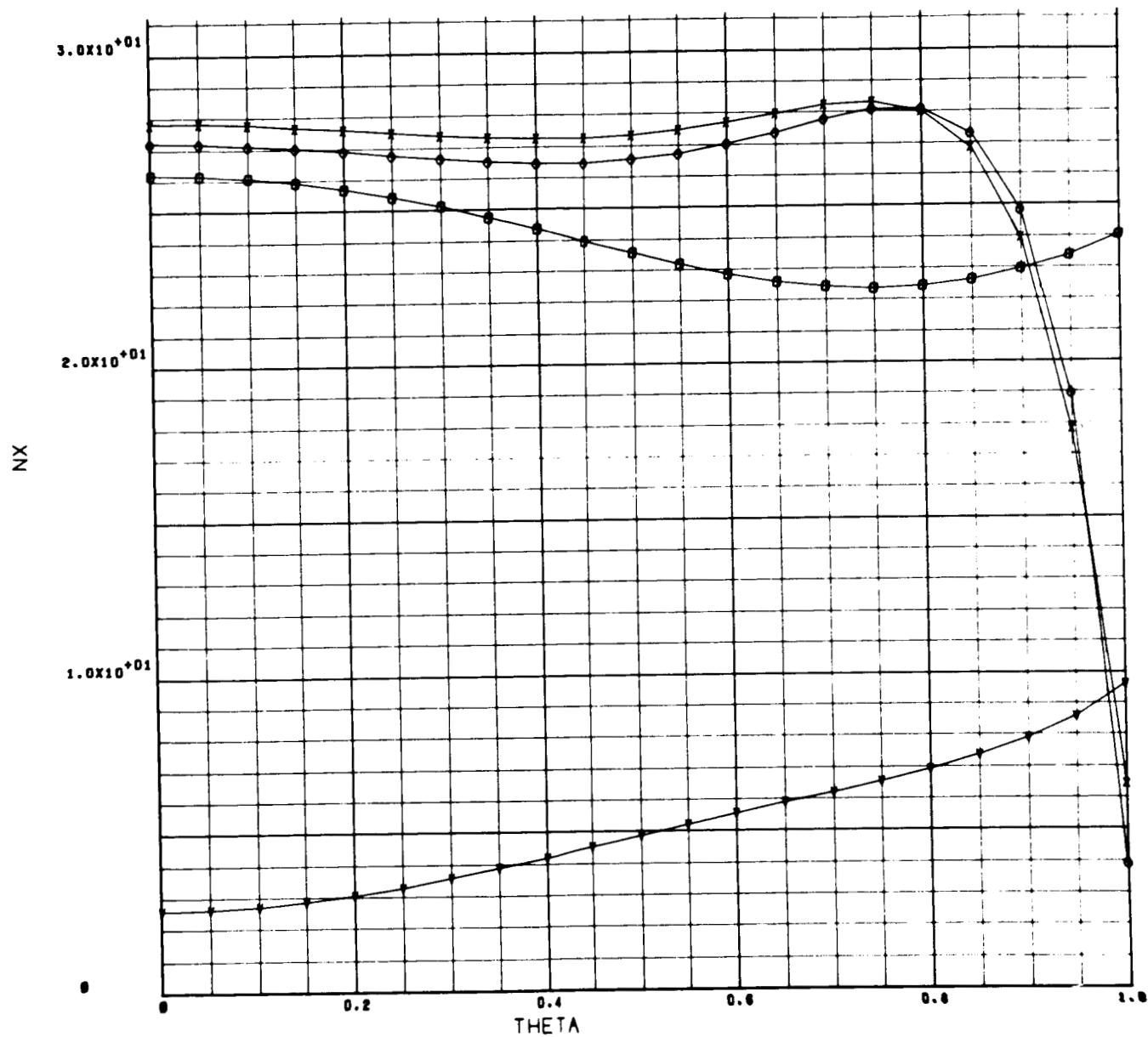
c - Cone Displacement Components

EXAMPLE UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

***SF7
004 000

G X=0.99375, ROW 1
X X=0.9875 ,ROW 2

G X=0.7 ,ROW 10
Y X=0.35 ,ROW 16



d - Cone Stress Resultants

EXAMPLE :UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

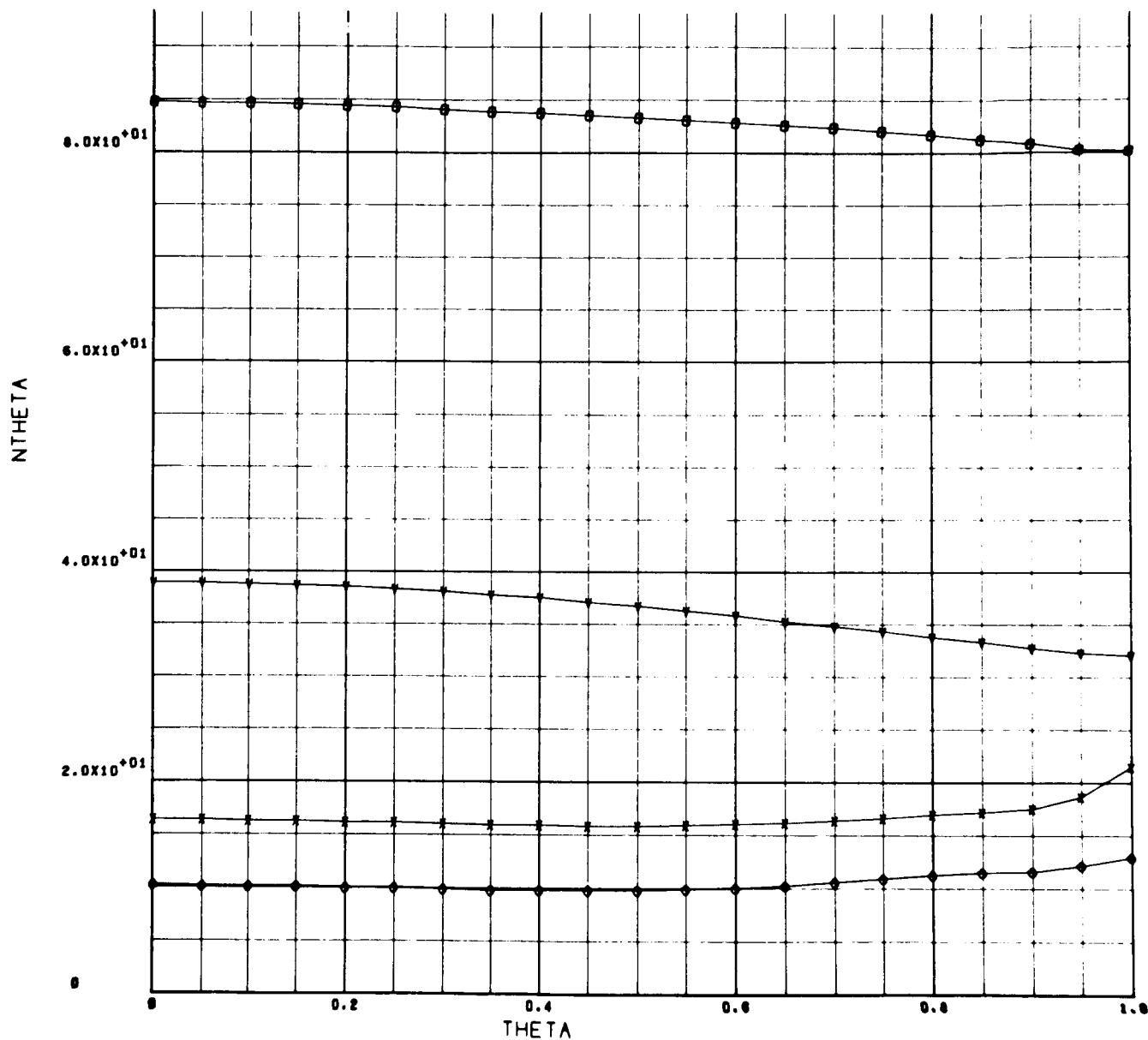
+08/57
005 000

G X=0.99375,ROW 1

G X=0.7 ,ROW 10

X X=0.9875 ,ROW 2

Y X=0.35 ,ROW 16



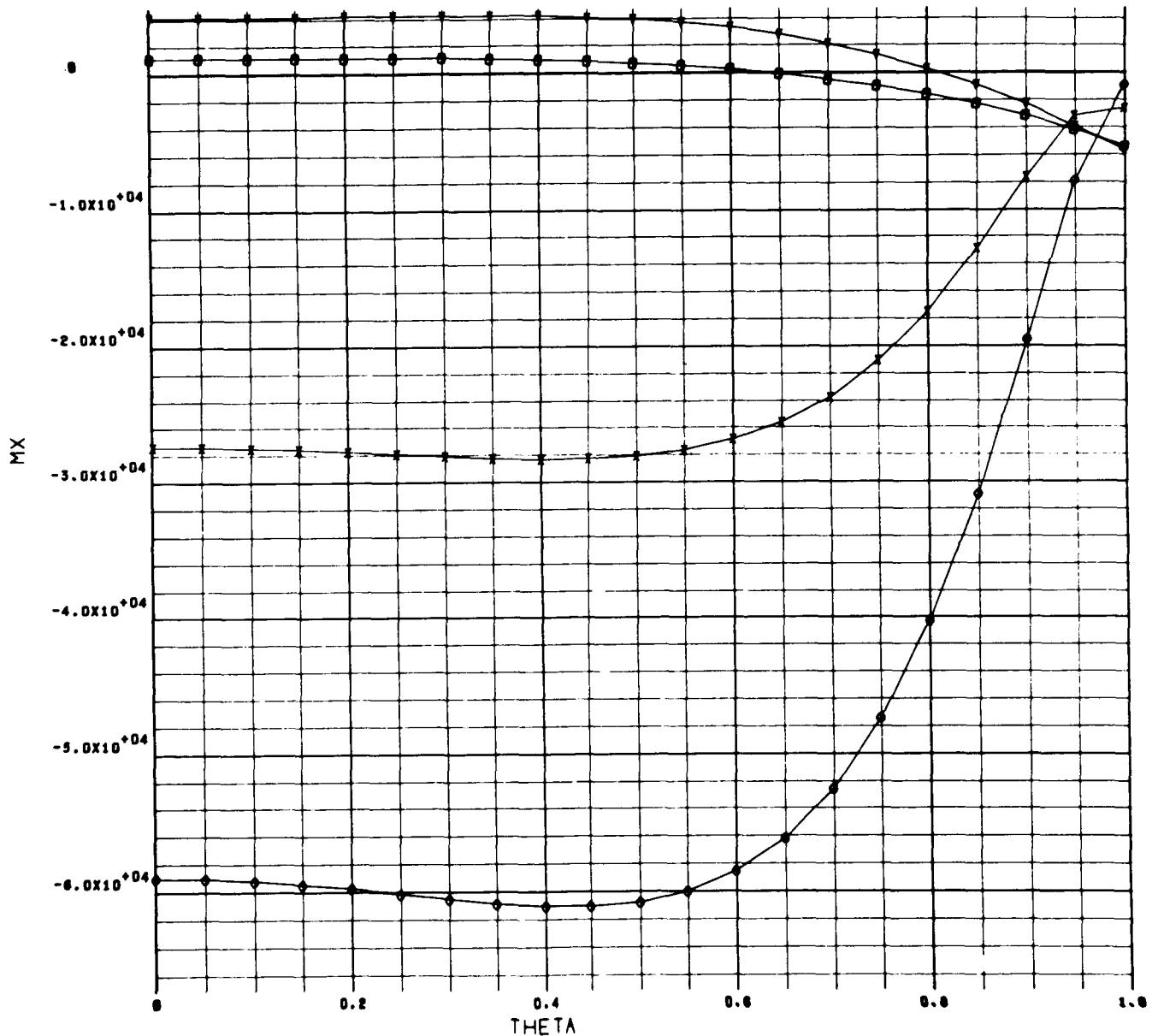
e - Cone Stress Resultants

EXAMPLE UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

***SF7
006 000

0 X=0.99375,ROW 1
X X=0.9875 ,ROW 2

0 X=0.7 ,ROW 10
Y X=0.35 ,ROW 16



f – Cone Stress Resultants

EXAMPLE UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

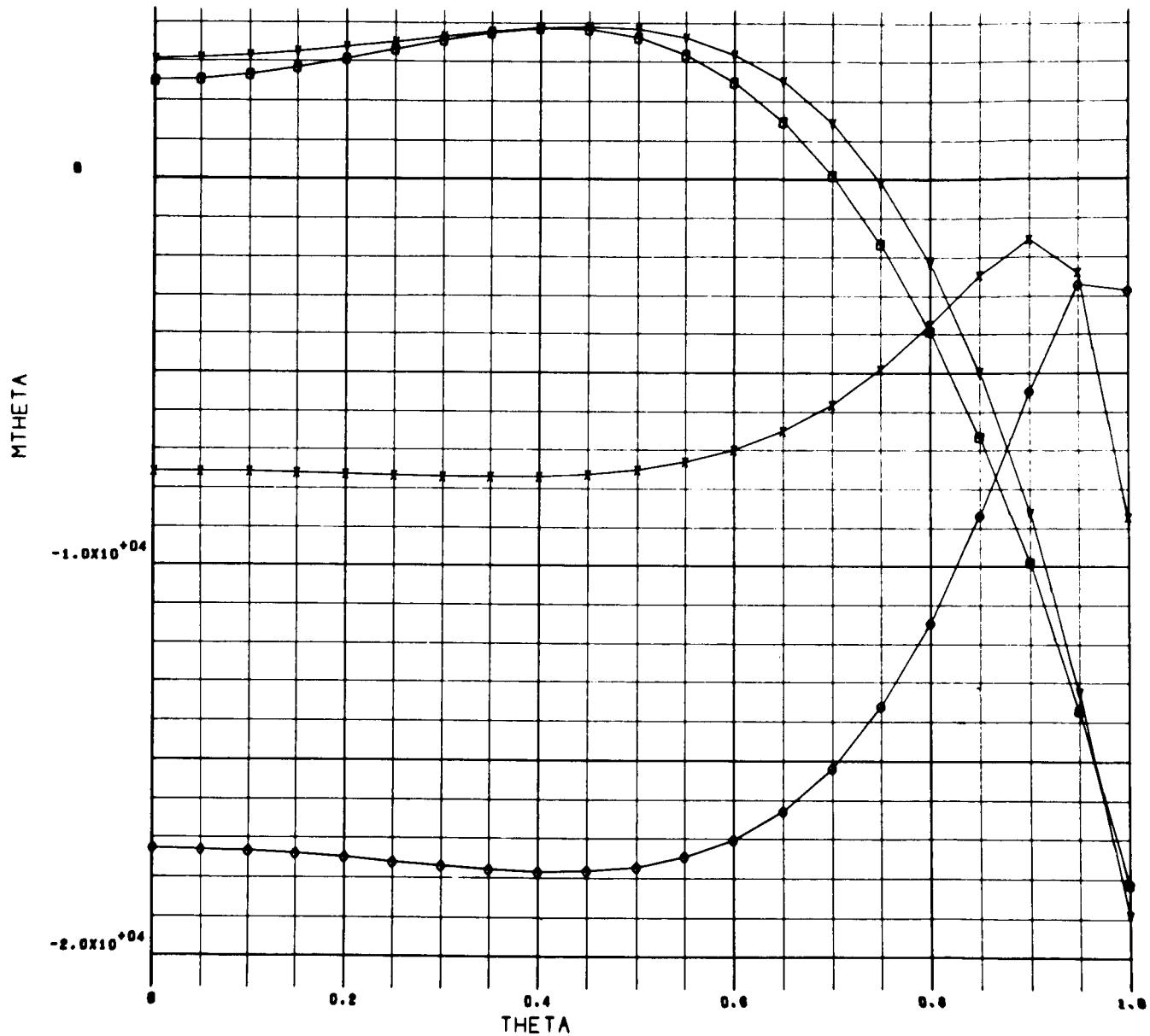
***SF7
007 000

G X=0.99375, ROW 1

G X=0.7 ROW 10

X X=0.9875 ,ROW 2

Y X=0.35 ROW 16



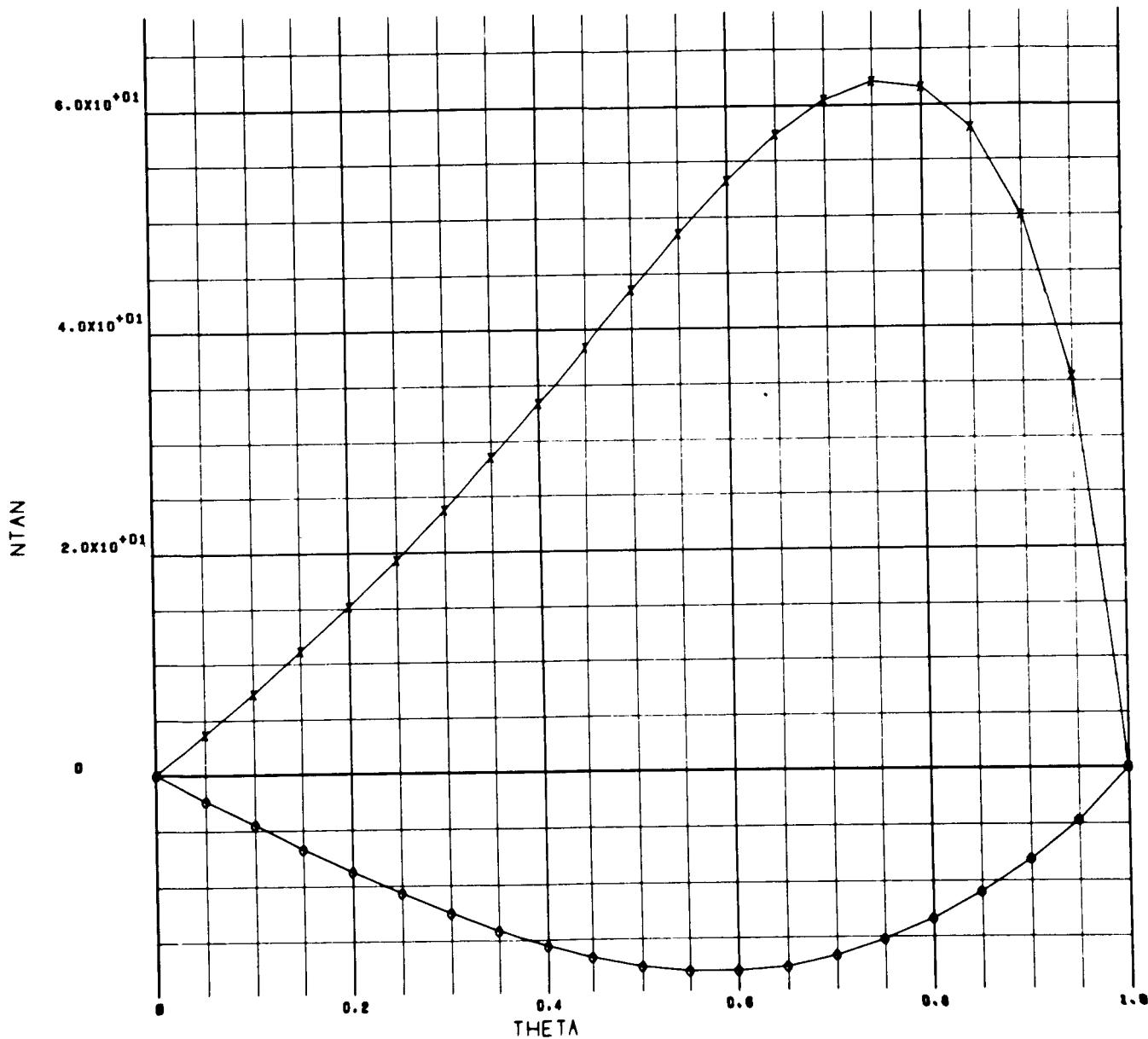
g - Cone Stress Resultants

EXAMPLE UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

++SF7
008 000

O CURVE 1= UPPER BOUNDARY

X CURVE 2= LOWER BOUNDARY

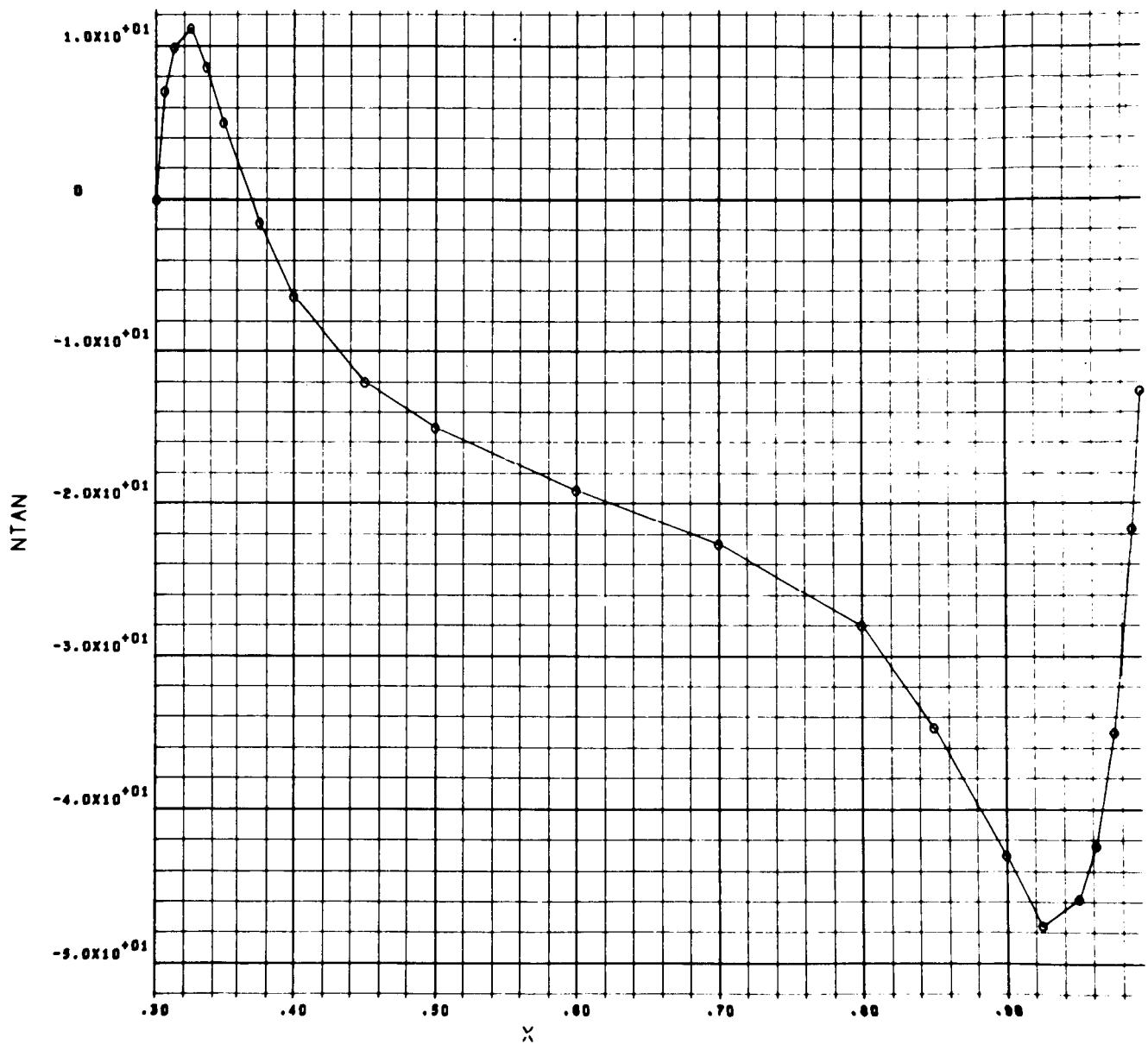


h – Cone Stress Resultants

EXAMPLE UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

+8FF7
000 000

O RIGHT BOUNDARY

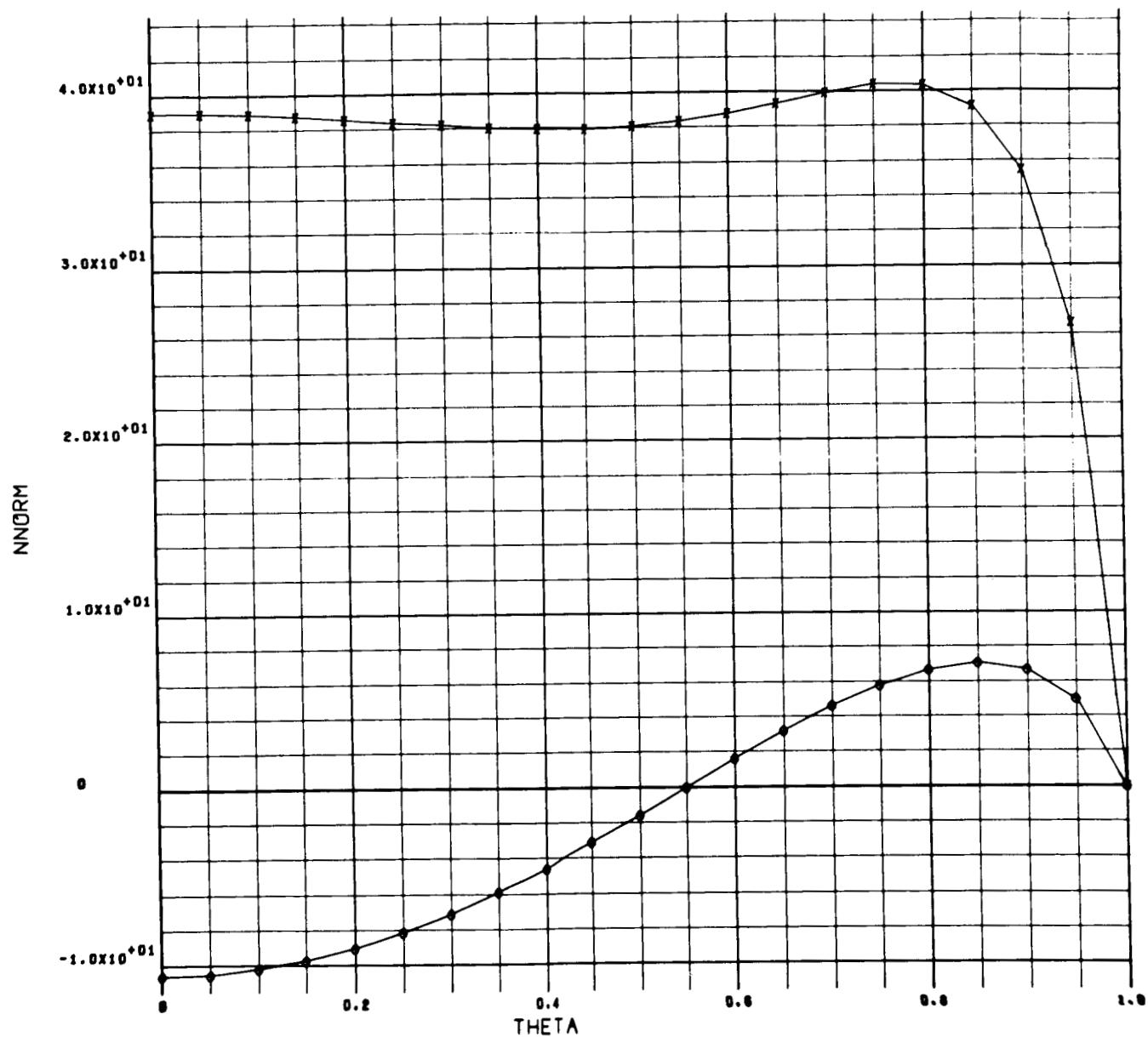


i - Boundary Stress Resultants

EXAMPLE UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

448SF7
010 000

- o CURVE 1= UPPER BOUNDARY
- x CURVE 2= LOWER BOUNDARY



j — Boundary Stress Resultants

EXAMPLE UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

***FF7
011 000

O RIGHT BOUNDARY



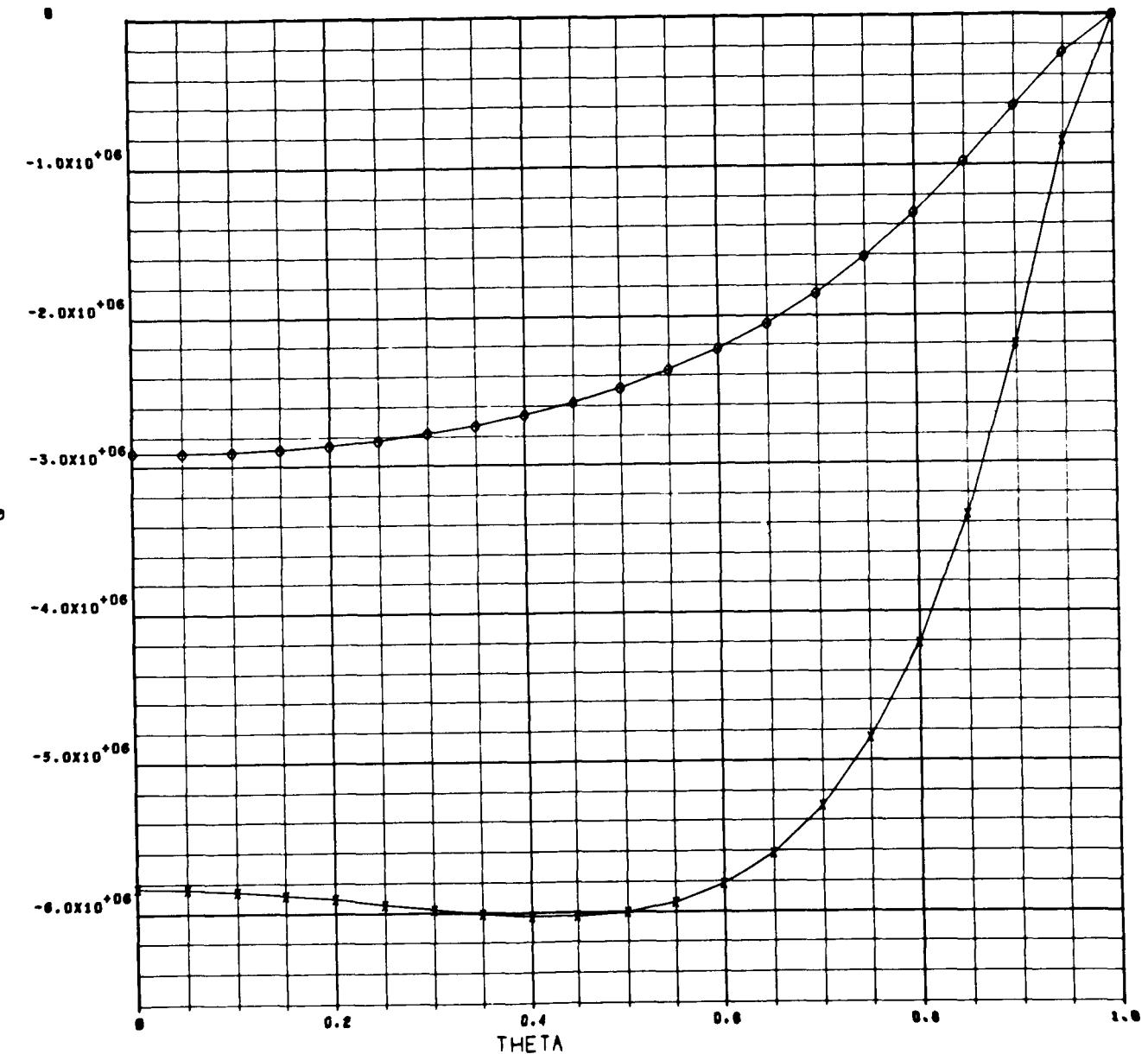
k - Boundary Stress Resultants

EXAMPLE UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

***SIF7
012 000

O CURVE 1= UPPER BOUNDARY

X CURVE 2= LOWER BOUNDARY

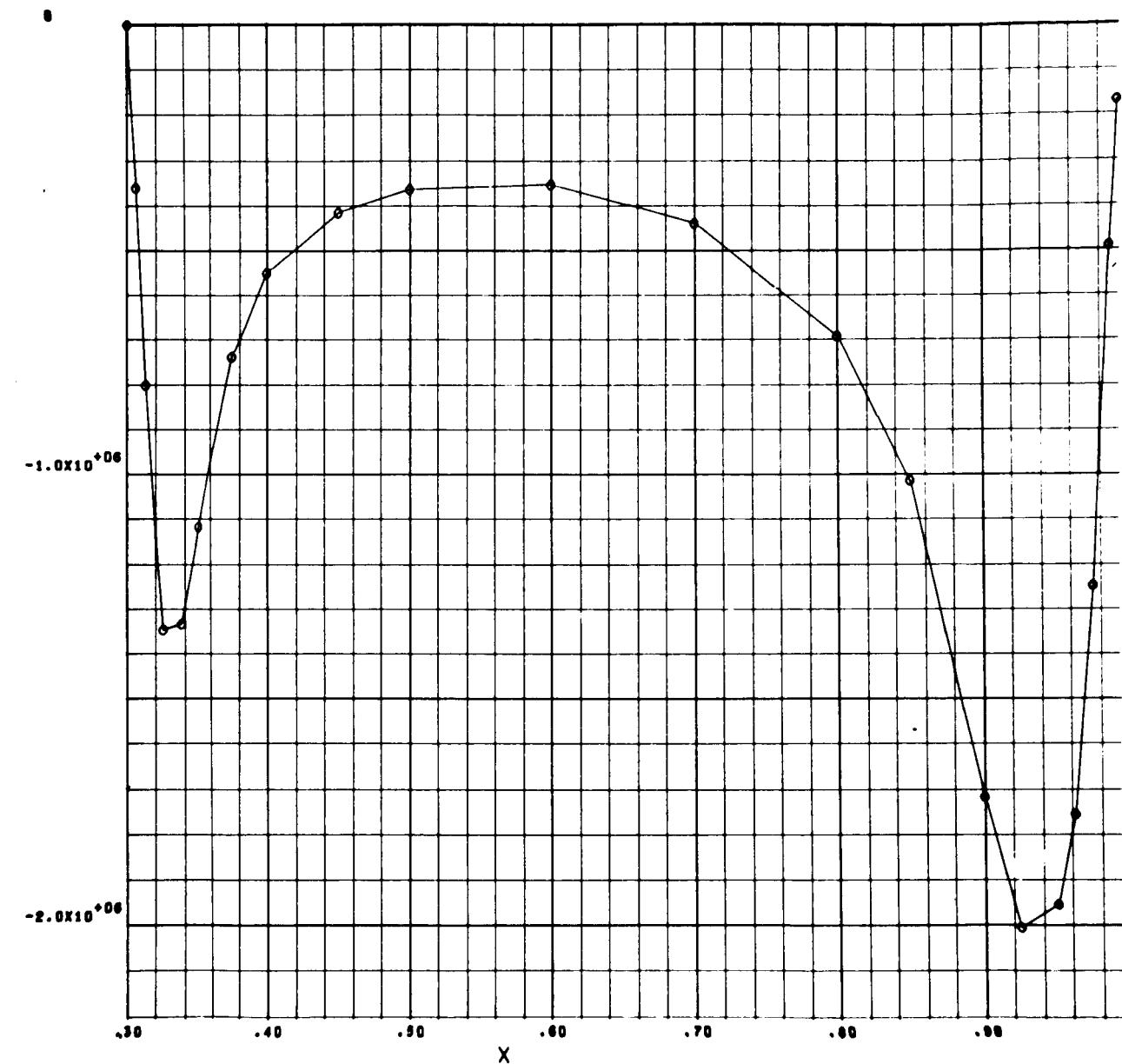


1 -- Boundary Stress Resultants

EXAMPLE UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

4857
013 000

G RIGHT BOUNDARY



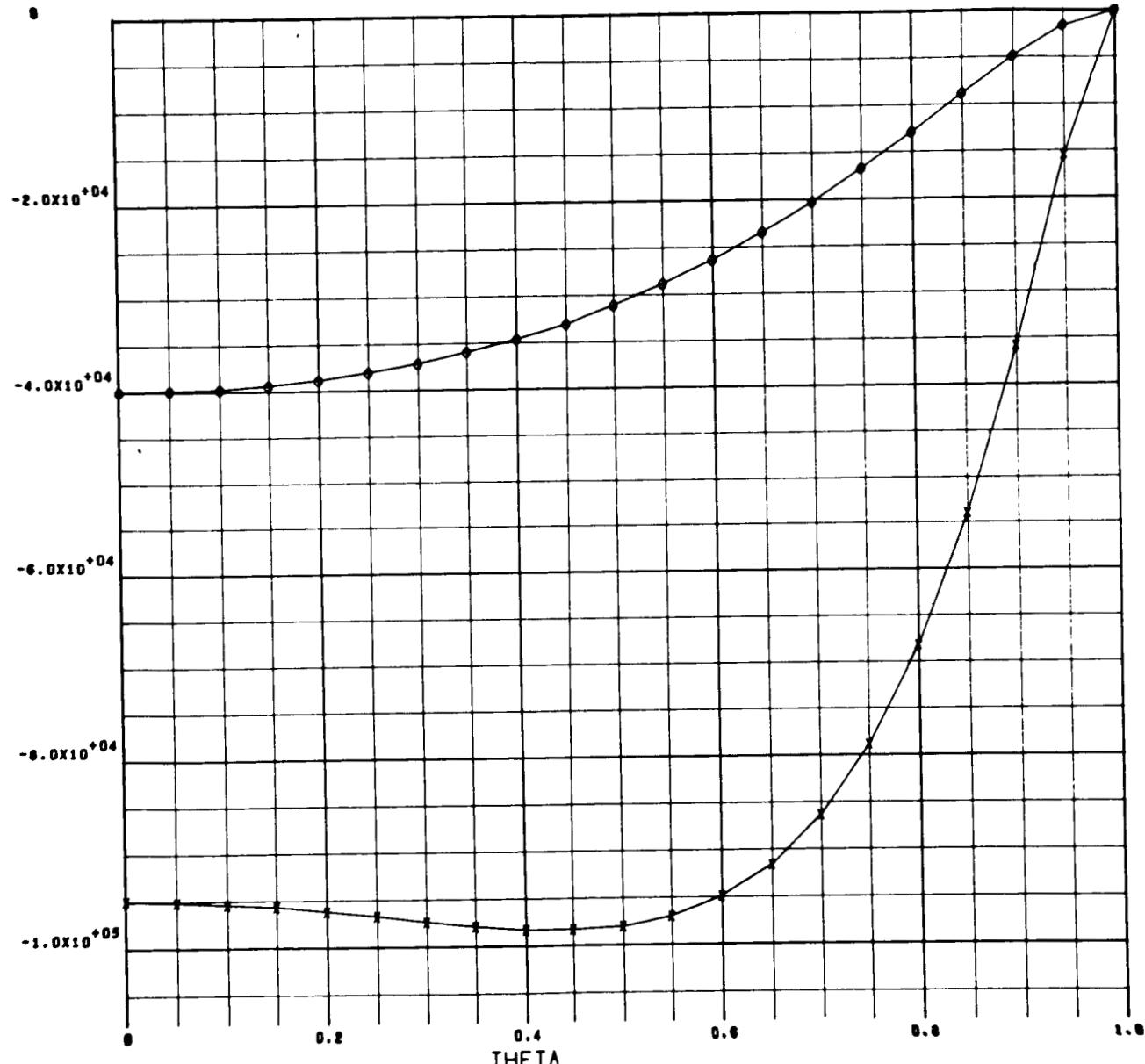
m - Boundary Stress Resultants

EXAMPLE UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

+88FF7
014 000

O CURVE 1= UPPER BOUNDARY

X CURVE 2= LOWER BOUNDARY

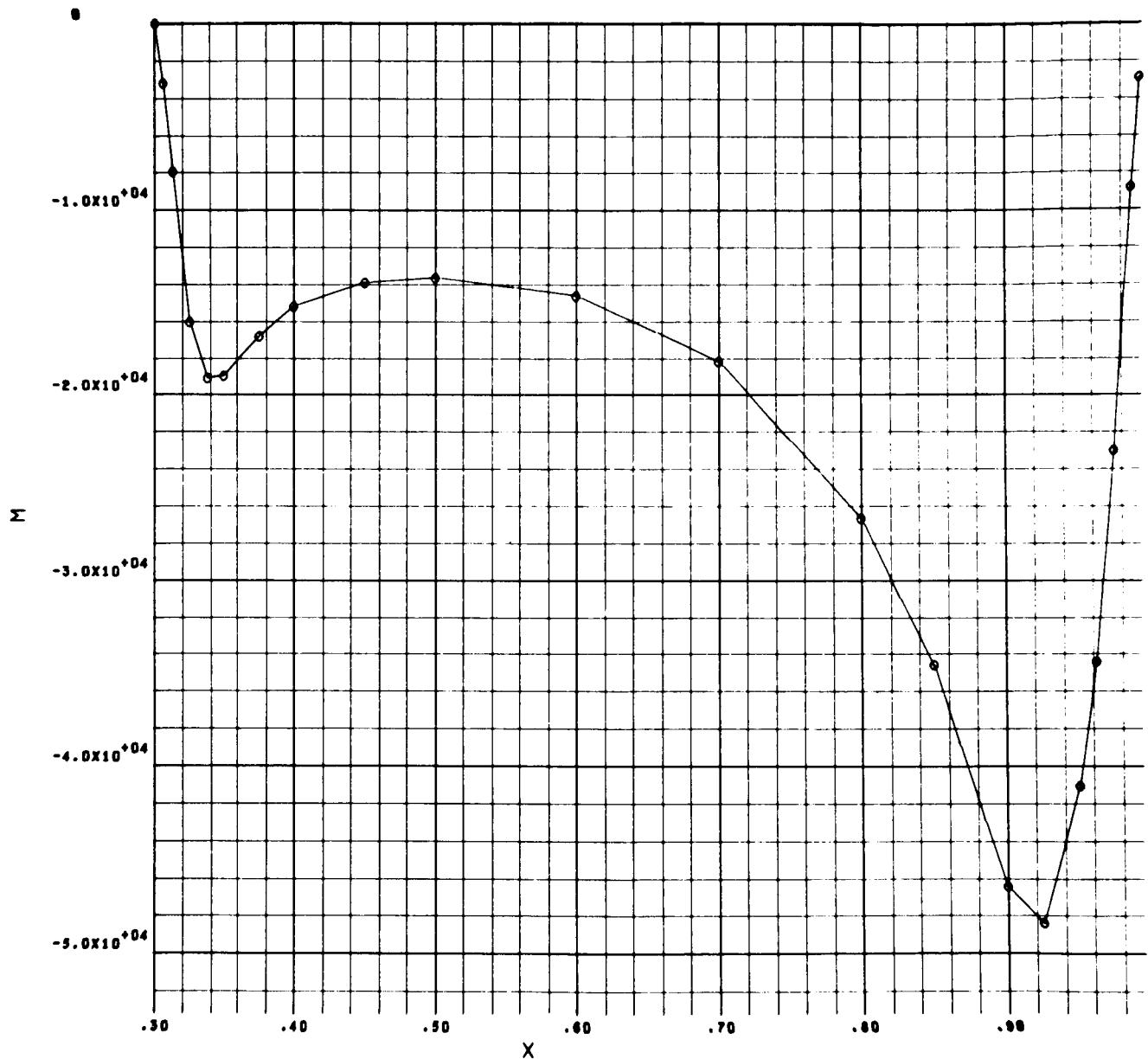


n — Boundary Stress Resultants

EXAMPLE UNIFORM THICKNESS CONE UNDER UNIFORM NORMAL PRESSURE

*#8FF7
015 000

o RIGHT BOUNDARY



o — Boundary Stress Resultants

4.3 LISTING OF THE PROGRAM

The complete source program is given in Table 6.

Table 6
STUDY OF JUNCTURE STRESS FIELDS: CONICAL SEGMENT

```

*   CHAIN (1,2)
*   FORTRAN
*   LIST
C   CB1P CONICAL SEGMENT * STUDY OF JUNCTURE STRESS FIELD*
C   BY SOLID MECHANICS * AEROSPACE SCIFNCS LABORATORY , 52-20
C   LOCKHEED MISSILES AND SPACE COMPANY, PALO ALTO CALIF
C   CONTRACT NAS 8-114800 TO NASA G.C. MARSHALL SPACE FLIGHT CENTER
C
C   THIS PROGRAM IS FOR USE ONLY ON FORTRAN II, VERSION 11
COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8
COMMON NDIM, NROW, NCOL, MM, MFLAG, XM,XLD
COMMON ISW1, ISW2, ISW3
COMMON A TMP, YK, YL
COMMON T1, T2, XX, XX1, Z, Z1, Z2
COMMON ZNU, THC, HBO, H1, XOXL, PH3, PH2, XH, XK
COMMON ZETA
COMMON TE, TI, TO, OC, TC, TD, DDLD
DIMENSION MM(40)
DIMENSION A (1064)
DIMENSION TMP(5184), YK(5184), YL(4,4,324)
DIMENSION T1( 89), T2(89), XX(89), XX1(89), Z(89), Z1(89), Z2(89)
DIMENSION ZETA (30)
DIMENSION DISP(9), STRSS(9), ORDLBL(6,11), ABLLBL(6,4)
DIMENSION ARSC(80), AORD(25), BOND(9)
DIMENSION CBLR( 6, 4)
DIMENSION AXLBL (6)
DIMENSION RECORD (12)
FORMAT (1H1, 12A6)
2 FORMAT (6E12.8)
3 FORMAT (1H1)
4 FORMAT (35I2)
5 FORMAT (1H1,3X,3HCOL , 15, 8I4/4H ROW)
6 FORMAT ( 14, 1P9E14.6)
7 FORMAT (10I1 )
B1P00010
B1P00020
B1P00030
B1P00040
B1P00050
B1P00060
B1P00070
B1P00080
B1P00090
B1P00100
B1P00110
B1P00120
B1P00130
B1P00140
B1P00150
B1P00160
B1P00170
B1P00180
B1P00190
B1P00200
B1P00210
B1P00220
B1P00230
B1P00240
B1P00250
B1P00260
B1P00270
B1P00280
B1P00290
B1P00300
B1P00310
B1P00320
B1P00330
B1P00340
B1P00350

```

```

8 FORMAT (12A6)
14 FORMAT (26HO FINITE DIFFERENCE MESH. 12, 7H ROWS, 12,27H COLUMNS
15. B1P00360
15. B1P00370
15. B1P00380
15. B1P00390
15. B1P00400
15. B1P00410
15. B1P00420
15. B1P00430
15. B1P00440
15. B1P00450
15. R*B1P00460
15. PR1P00470
15. B1P00480
15. R1P00490
15. B1P00500
15. B1P00510
15. B1P00520
15. R1P00530
15. R1P00540
15. R1P00550
15. R1P00560
15. B1P00570
15. B1P00580
15. B1P00590
15. B1P00600
15. B1P00610
15. B1P00620
15. B1P00630
15. B1P00640
15. B1P00650
15. B1P00660
15. B1P00670
15. B1P00680
15. B1P00690
15. B1P00700
15. R1P00710
15. R1P00720
15. R1P00730
15. R1P00740

1. MESH SPACING. H= F15•7, 4H, K= E15•7 )
1. 6H, HBO= 1PE12•5, 5H, H1= 1PE12•5, 8H, X0/XL= 1PE12•5, 7H, PHI3=
2 1PF12•5 )
16 FORMAT (39HO A DIAGONAL SUBMATRIX IS SINGULAR, J= 13, )
17 FORMAT (42HO CONE DISPLACEMENT COMPONENTS (U, V, W) /
1 10HO COL ROW * 17X, 1HU, 15X, 1HW )
18 FORMAT (53H ROW COL NX NTHETA NXTHETA NTHETAX )
19 FORMAT (125HOROW COL EPSX EPST GAMMA
1X1 R*X12 OMEGAX OMEGAT
2H1 )
20 FORMAT (26HO CONF STRESS RESULTANTS. )
919 FORMAT (34H GRADED MESH IN ZETA DIRECTION )
920 FORMAT (2X, 4H ROW, 15I8 / 6X, 15I8)
921 FORMAT (6H ZETA= , 15F8•5 / 6X, 15F8•5 )
925 FORMAT (25HUNIFORM RADIAL PRESSURF )
926 FORMAT (20HODFAD LOAD. PHI2= F9•4 )
930 FORMAT (1H 13, 1H, 13, 10X, 1P3E16•6 )
931 FORMAT (1H 13, 1H, 13,10H BOUNDARY 10X, 1P3E16•6 )
936 FORMAT (30HO BOUNDARY STRESS RESULTANTS. /84HOROW COL NTAN
1 NNORM Q RBAR M )
1 FORMAT(13,1H, 13, 1P5E12•4 )
938 FORMAT (13, 2H, 13, 66X, 1PE16•7 )
939 FORMAT (59HO CONE STRAINS, CHANGES OF CURVATURE AND ROTATION
1N. )
1 FORMAT (1HO // 8H CASE NR 12,13H COMPLETED IN F8•3, 9H MINUTES. )
951 FORMAT (33HOLINEAR TEMPERATURE GRADINT. TF=E15•7,5H, TI=E15•7,
1 5H, TO=E15•7, 5H, OC=F15•7 )
962 FORMAT (9OH ROW COL MX MTHETA MXTHETA QX
1 QTHETA )
1 FORMAT (6A6)
1 SET TAPE ASSIGNMENTS.
1 KTAPE=15
1 MTAPE=7
1 XMTP=000000002221
1 XZTP=000000002223
1 XNTP=000000001224

```

```

NTAPF=4
IZTAPF=3
REWIND KTAPE
REWIND MTAPE
REWIND NTAPE
REWIND IZTAPE
CALL WTAP (XZTP, TEMP, 15000, 0)
BLNK=606060606060
XLBL=606067606060
B B READ AND WRITE INPUT DATA
C CALL CLOCK (TIME)
C READ INPUT TAPF 5, 8, RECORD
C WRITE OUTPUT TAPE 6, 1, RECORD
C IOPT1 = 0 CONSTANT MESH SPACING
C IOPT1 = 1 GRADFD MESH SPACING IN X DIRECTION
C IOPT2 = 0 UNIFORM NORMAL PRESSURE
C IOPT2 = 1 DEAD LOAD FUNCTION OF PH2
C IOPT2 = 2 LINEAR TEMPERATURE GRADIENT
C IOPT3 = 0 OMIT CONE STRAINS, CHANGES IN CURVATURE AND ROTATION
C IOPT3 = 1 PRINT OUT STRAINS , ETC.
C IOPT4=0 PREPARE AUXILIARY PLOT TAPE. NO SC4020 PLOT TAPE
C IOPT4=1 PREPARE SC4020 PLOT TAPE FROM AUXILIARY TAPE
C READ INPUT TAPE 5, 7, IOPT1,IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT781P00970
1 , IOPT8
XM = IOPT1
XLD = IOPT2
NSTP=IOPT4
IOPT4=0.
READ INPUT TAPE 5, 2, ROW, COL, XH, XK
READ INPUT TAPE 5, 2, ZNU, THC, HBO, H1, X0XL, PH3
NROW=ROW
NCOL=COL
NC1=NCOL+1
NR1=NROW+1
NR3=3*(NROW+6)
ITOT=(NROW+6)*3
WRITE OUTPUT TAPE 6,14, NROW, NCOL, XH, XK
WRITE OUTPUT TAPE 6, 15, ZNU, THC, HBO, H1, X0XL, PH3
IF (IOPT1) 23,23,22
R1P000750
R1P000760
B1P000770
B1P000780
B1P000790
B1P000800
B1P000810
B1P000820
B1P000830
B1P000840
B1P000850
B1P000860
B1P000870
B1P000880
B1P000890
B1P000900
B1P000910
B1P000920
B1P000930
B1P000940
B1P000950
B1P000960
B1P000970
B1P000980
B1P000990
B1P01000
B1P01010
B1P01020
B1P01030
B1P01040
B1P01050
B1P01060
B1P01070
B1P01080
B1P01090
B1P01100
B1P01110
B1P01120
B1P01130

```

```

22 READ INPUT TAPE 5, 4, (MM(I), I=1,NROW)
      MM(NR1)=MM(NROW)
      WRITE OUTPUT TAPE 6, 919
      GO TO 26
23 DO 24 J=1,30
24 MM(J)=0
25 YK(0)=1.
26 ZFTA(1)=1.
      X=1.-XH/2.*MM(1)
      YK(1)=X
      ZETA(2)=X
      DO 30 J=2, NROW
      IF (MM(J)-MM(J-1)) 27, 27, 28
27 JM=MM(J)
      GO TO 29
28 JM=MM(J-1)
29 X=X-XH/2.*JM
      YK(J)=X
      ZETA(J+1)=X
30 CONTINUE
      YK(NR1)=X0XL
      ZETA(NR1+1)=X0XL
      WRITE OUTPUT TAPE 6, 920, (I, I=0, NR1)
      WRITE OUTPUT TAPE 6, 921, (YK(I), I=0, NR1)
      NDIM=3*NROW
      NSM=NDIM-NROW
      NSQ=72*NDIM
      IF (IOPT2-1) 82, 83, 90
82 WRITE OUTPUT TAPE 6, 925
      GO TO 84
83 READ INPUT TAPE 5, 2, PH2
      WRITE OUTPUT TAPE 6, 926, PH2
      GO TO 84
90 CONTINUE
106 READ INPUT TAPE 5, 2, TE, TI, TO, OC
      WRITE OUTPUT TAPE 6, 951, TE, TI, TO, OC
      TT1 = (TE + TI)/2. - TO
      TT2 = (TE - TI)
      TC = (1.+ ZNU)*OC*TT1

```

```

TD = (1.+ZNU)*OC*TT2          B1P01530
84 CONTINUE                      B1P01540
      READ INPUT TAPE 5, 4, (MM(I), I=31, 35)
      IF (MM(31)) 79, 51           B1P01550
51      READ INPUT TAPE 5, 966, ((CILBL(I, J), I=1, 6), J=1, 4)
      NEND=0
      NCRV=MM(31)
      NCRV1=2                      B1P01560
      NPTS=NCOL/26+1              B1P01570
      NFLAG=1                      B1P01580
      CALL PLTLBL (DISP, STRSS, ORDLBL, ABLBL, BOND)
      TH=0.                         B1P01590
      DELH=1./COL                  B1P01600
      DO 52 I=1, NC1               B1P01610
      ABSC(I)=TH                  B1P01620
      52   TH=TH+DFLH             B1P01630
      DO 53 J=1, NR1               B1P01640
      JJ=NR1+1-J                  B1P01650
      ABSC(J)=YK(JJ)             B1P01660
      53   AORD(J)=YK(JJ)         B1P01670
      AORD(NR1+1)=1.              B1P01680
      DO 57 I=1, 6                B1P01690
      57   ALBL(I)=BLNK            B1P01700
      ALBL(3)=XLBL
      79 CONTINUE
      CALL COEFZ
      MFLAG=0
      IF (KTIME) 81,81,400
81 CONTINUE
      C   SPACE TAPES OVER FIRST ACCIDENT PRONE SECTION
      CALL WTAPE (XNTP, TFMP, 15000, 0)
      CALL WTAPE (XMTP, TEMP, 15000, 0)
      COMPUTE L, M, N AND Z MATRICES OF FORWARD SWEEP
      400 KTIME=KTIME+1
      N1=NSM
      N2=NSM
      N3=NSM
      I=1
      GO TO 405

```

```

401 CALL WTAPE (XZTP,Z1,N1,1)
CALL RTAPE (XMTP,TMP, NSQ, 0)
CALL MTX (YK, 1, 2)
IF (I-2) 405, 403, 402
402 CALL BACK (XNTP)
CALL ZFRO (YL, NSQ)
CALL RTAPE (XMTP, TMP, NSQ, 1)
CALL MTXS (TMP, YL, 1, 1)
CALL RTAPE (XMTP, TMP, NSQ, 0)
CALL ADDM (YK, YL, YK, -NSQ)
CALL RTAPE (XNTP, YL, NSQ, 0)
403 N1=NDIM
CALL RTAPE (XMTP, TMP, NSQ, 1)
CALL MATM (YK, TMP, TMP, NDIM, N2, NDIM)
IF (I-2) 405, 404
404 CALL RTAPE (XNTP, YL, NSQ, 1)
CALL MTXS (YL, TMP, I, 1)
405 CALL MTX (YL, 1, 3)
IF (I-2) 408, 406, 406
406 CALL ADDM (YL, TMP, YL,-NSQ)
IF (I-NCOL) 407, 408, 408
407 CALL RTAPE (XNTP, TMP, NSQ, 0)
408 CALL INVERT (YL, N1, ISING)
IF (I-1) 414, 414, 410
410 CALL MATM (YK, Z1, T2, NDIM, N2,1)
IF (I-NCOL) 411, 421, 421
411 CALL RTAPE (XNTP, TMP, NSQ, 1)
CALL MATM (YK, TMP, TMP, NDIM, N2, NDIM)
414 CALL MTX (YK, 1, 4)
IF (I-2) 417, 416, 416
416 CALL ADDM (YK, TMP, YK, -NSQ)
417 IF (I-NCOL+1) 418, 419, 419
418 CALL ZERO (TMP,NSQ)
CALL MTXS (YL, TMP, 1, 5)
CALL WTAPE (XNTP, TMP, NSQ, 0)
419 CALL MATM (YL, YK, YK, N1, N1, NDIM)
CALL WTAPE (XMTP, YK, NSQ, 0)
IF (I-NCOL+1) 420, 421, 421
420 CALL WTAPE (XNTP, TMP, NSQ, 1)
B1P01910
B1P01920
B1P01930
B1P01940
B1P01950
B1P01960
B1P01970
B1P01980
B1P01990
B1P02000
B1P02010
B1P02020
B1P02030
B1P02040
B1P02050
B1P02060
B1P02070
B1P02080
B1P02090
B1P02100
B1P02110
B1P02120
B1P02130
B1P02140
B1P02150
B1P02160
B1P02170
B1P02180
B1P02190
B1P02200
B1P02210
B1P02220
B1P02230
B1P02240
B1P02250
B1P02260
B1P02270
B1P02280
R1P02290

```

```

CALL BACK (XNTP)                                B1P02300
421 CALL CONS(T1,I)                            B1P02310
    IF (I-1) 426, 426, 422                      B1P02320
422 CALL ADDM (T1, T2, T1, -NDIM)              B1P02330
    IF (I-2) 426, 424, 423                      B1P02340
423 CALL MTXS (Z2, T2, I,-1)                  B1P02350
424 DO 425 J=1,NDIM                           B1P02360
425 Z2(J)=Z1(J)
    IF (I-NCOL) 426, 428, 428                 B1P02370
426 CALL WTAPE (XMTP, YK, NSQ, 1)             B1P02380
    CALL BACK (XMTP)                           B1P02390
        IF (I-2) 430, 429, 428                 B1P02400
428 CALL ADDM (T1, T2, T1,-NDIM)              B1P02410
429 CALL BACK (XMTP)                           B1P02420
430 CALL MATM (YL, T1, Z1, N1, N1, 1)         B1P02430
    CALL WTAPE (XZTP, Z1, N1, 0)               B1P02440
    IF (I-NCOL) 431, 450, 450                 B1P02450
431 IF (I-2) 434,433,432                     B1P02460
432 N3=NDIM                                     B1P02470
433 N2=NDIM                                     B1P02480
434 I=I+1                                       B1P02490
    GO TO 401                                     B1P02500
C   DECOMPOSITION COMPLETED • BEGIN BACKWARD SWEEP.
450 CALL WTAPE (XZTP, Z1, N1,1)                B1P02510
    CALL BACK (XZTP)                           B1P02520
        N4= (NCOL+3)*(NROW+6)*3                B1P02530
        CALL ZERO (TMP,N4)                     B1P02540
451 IF (I-NCOL) 452,454,454
452 DO 453 J=1,NDIM                           B1P02550
    XX1(J)=XX(J)
453 XX(J)=Z1(J)
    CALL RTAPE (XMTP, YK, NSQ, 1)             B1P02560
    CALL BACK (XMTP)                           B1P02570
        IF (I-1) 454, 454, 4541
4541 CALL BACK (XMTP)                         B1P02580
    454 CALL RTAPE (XZTP, Z1, N1, 0)           B1P02590
    CALL RTAPE (XZTP, Z1, N1, 1)               B1P02600
    IF (I-1) 4543, 4543, 4542                 B1P02610
                                                B1P02620
                                                B1P02630
                                                B1P02640
                                                B1P02650
                                                B1P02660
                                                B1P02670
                                                B1P02680

```

```

4542 CALL BACK (XZTP)
4543 CALL BACK (XZTP)
    IF (I-NCOL+1) 456,457,462
456  CALL RTAPE (XNTP, YL, NSQ, 0)
457  CALL MATM( YK, XX, T1, N1, NDIM, 1)
    CALL ADDM (Z1, T1, Z1, -NDIM)
    IF (I-NCOL+1) 458,462,462
458  CALL RTAPE (XNTP, YL, NSQ, 1)
    IF (I-1) 4591, 4591, 459
459  CALL BACK (XNTP)
4591 CALL BACK (XNTP)
    CALL MATM (YL, XX1, T1, N1, NDIM)
    CALL ADDM (Z1, T1, Z1, -NDIM)
460  IF (I-2) 463,461,462
461  N1=NSM
462  CALL RTAPE (XMTP, YK, NSQ, 0)
463  CALL STORE (Z1, I)
    IF (I-2) 500, 464, 464
464  I=I-1
    GO TO 452
500  MFLAG=1
140  L0=6
    DO 141 L=1, NCOL
        TMP(L0)=TMP(L0+6)
141  L0=L0+ITOT
    L1=L0-ITOT
    L0=L0+ITOT
    TMP(L0)=TMP(L1)
145  L0=NC1*ITOT+12
    DO 147 J=1, NROW
        L1=L0-2*ITOT
        TMP(L0)=TMP(L1)
147  L0=L0+3
    L0=L0+3
    TMP(L0)=TMP(L1)
    L0=L0-ITOT
    DO 148 I=1, NCOL
        L0=L0-ITOT
        TMP(L0)=TMP(L1)

```

```

148 L1=L1-ITOT
      CALL BOUND
      IOUT=51
      NC2=NCOL+3
502   NR2=NROW+6
      DO 520 I=1, NC2
      I3=I*(NROW+6)*3
      I2=I3-1
      I1=I2-1
      IF (IOUT+NR2-50) 505, 505, 504
      WRITE OUTPUT TAPE 6, 1
      WRITE OUTPUT TAPE 6, 17
      IOUT=6
505   DO 515 JJ=1, NR2
      J=NROW-JJ+4
      IF (J-NR1) 506, 511, 510
506   IF (J) 510, 511, 510
510   WRITE OUTPUT TAPE 6, 930, I, J, TMP(I1), TMP(I2), TMP(I3)
      GO TO 514
511   WRITE OUTPUT TAPE 6, 931, I, J, TMP(I1), TMP(I2), TMP(I3)
      GO TO 514
514   I1=I1-3
      I2=I2-3
      I3=I3-3
515   IOUT=IOUT+1
520   CONTINUE
521   ISW3=1
      IOUT=50
      L=32
      K=0
      DO 540 J=0, NR1
      IF (LOPT1) 537, 537, 536
536   CALL GRADE (J)
537   IF (MM(31)) 5378, 5378, 5370
5370  IF (MM(L)-J) 5378, 5372, 5378
5372  IF (L-35) 5374, 5374, 5378
      L=L+1
      K=K+1

```

```

K1=K
GO TO 5380
5378 K1=0
5380 DO 540 I=1, NC1
      IF (IOUT=41) 539, 538, 538
538 WRITE OUTPUT TAPE 6, 1, RECORD
      IOUT=0
      IF (MFLAG) 532, 530, 531
531 WRITE OUTPUT TAPE 6, 20
      WRITE OUTPUT TAPE 6, 18
      GO TO 539
530 WRITE OUTPUT TAPE 6, 20
      WRITE OUTPUT TAPE 6, 962
      GO TO 539
532 WRITE OUTPUT TAPE 6, 939
      WRITE OUTPUT TAPE 6, 19
539 IOUT=IOUT+1
      CALL STRESS (I,J,K1)
540 CONTINUE
      IF (MFLAG) 999, 544, 541
541 MFLAG=0
      GO TO 521
544 WRITE OUTPUT TAPE 6, 1, RECORD
      I0=0
      I1=1
      I2=4
      WRITE OUTPUT TAPE 6, 936
      I=1
      DO 560 JJ=1, NR1
          J=NR1+1-JJ
550      WRITE OUTPUT TAPE 6, 937, J, I, (YK(I3), I3=I1, I2)
          I1=I1+4
          I2=I1+3
          IF (I-NCOL) 551, 552, 560
551      I=I+1
          GO TO 550
552      I=NC1
      WRITE OUTPUT TAPE 6, 937, J, NC1, (YK(I3), I3=I1, I2)
      K1=8*(NC1+NR1)-3

```

```

      WRITE OUTPUT TAPE 6, 938, J, NC1, YK(K1)
      IF (NC1+NR1-45) 554, 554, 553
      553 WRITE OUTPUT TAPE 6, 1, RECORD
      WRITE OUTPUT TAPE 6, 936
      554 CONTINUE
      I1=I1+4
      I2=I1+3
      GO TO 550
      560 CONTINUE
      562 WRITE OUTPUT TAPE 6, 937, 10, NC1,(YK(I3), I3=I1, 12)
      K1=K1+4
      WRITE OUTPUT TAPE 6, 938, 10, NC1, YK(K1)
      I1=I1+4
      I2=I1+3
      WRITE OUTPUT TAPE 6, 1, RECORD
      WRITE OUTPUT TAPE 6, 936
      DO 565 I1=1, NC1
      I=NC1+1-I1
      WRITE OUTPUT TAPE 6, 937, 10, I, (YK(I3), I3=I1, 12)
      I1=I1+4
      I2=I1+3
      565 CONTINU
      566 IF(IOPT3) 999,999,545
      545 MFLAG=-1
      XM=0.
      GO TO 521
      999 CONTINUE
      80 CALL CLOCK (TIM2)
      TIME=TIM2-TIM1
      TIM1=TIM2
      PRINT 945, KTIME, TIME
      WRITE OUTPUT TAPE 6, 945, KTIME, TIME
      IF (MM(31)) 1000, 1000, 601
      601 DO 650 K=1,3
      WRITE TAPE KTAPE, RECORD
      WRITE TAPE KTAPE, NC1, NCRV, NPTS, NEND, NFLAG
      WRITE TAPE KTAPE, ABLBL, (ORDLBL(M,K),M=1,6), DISP
      WRITE TAPE KTAPE, CILBL
      DO 610 I=1, NC1

```

```

      WRITE TAPE KTAPE, ABSC(I1)
      CONTINUE
      L=32
      L3=31+MM(31)
      DO 620 J=0, NR1
        IF (MM(L)-J) 620, 611, 620
      611 I1=3*(J+2)+K
      DO 615 I=1, NC1
        WRITE TAPE KTAPE, TMP(I1)
      615 I1=I1+NR3
      L=L+1
      IF (L-L3) 620, 620, 650
      620 CONTINUE
      650 CONTINUE
      DO 720 K=1, 4
        K1=K+3
        WRITE TAPE KTAPE, RECORD
        WRITE TAPE KTAPE, NC1, NCRV, NPTS, NFND, NFLAG
        WRITE TAPE KTAPE, ABLBL, (ORDLBL(M, K1), M=1, 6), STRSS
        WRITE TAPE KTAPE, CILBL
        DO 662 I=1, NC1
          WRITE TAPE KTAPE, ABSC(I)
        662 CONTINUE
        DO 660 M=1, NCRV
        660 I=1, NC1
        660 WRITE TAPE KTAPE, YL(K,M,I)
        720 CONTINUE
        DO 740 K1=1, 4
          K=K1+7
        NCRV=NCRV1
        NCR=0
        NCX=NC1
      725 WRITE TAPE KTAPE, RECORD
        WRITE TAPE KTAPE, NCX, NCRV, NPTS, NEND, NFLAG
        IF (NCR) 723, 723, 724
      723 CONTINUE
        WRITE TAPE KTAPE, ABLBL, (ORDLBL(M,K), M=1, 6), BOND
        GO TO 726
      724 CONTINUE

```

```

      WRITE TAPE KTAPE, AXLBL, (ORDLBL(M, K), M=1, 6), BOND
726 CONTINUF          B1P04630
      CALL PLBL (CBLBL, NCR)    B1P04640
      WRITE TAPE KTAPE, CRLBL  B1P04650
      IF (NCR) 727, 727, 729  B1P04660
727 DO 728 I=1, NC1       B1P04670
728 WRITE TAPE KTAPE, ABSC(I)
      I1=K1                  B1P04680
      GO TO 731              B1P04690
729 DO 730 I=1, NR1       B1P04700
730 WRITE TAPE KTAPE, AORD(I) B1P04710
731 CONTINUE             B1P04720
      KAD=4                 B1P04730
      DO 735 M=1, NCRV        B1P04740
      DO 732 L=1, NCX          B1P04750
      WRITE TAPE KTAPE, YK(I1) B1P04760
732 I1=I1+KAD            B1P04770
      I1=4*(NC1+NC1+NR1)+K1  B1P04790
733 KAD=-4               B1P04800
      IF (NCR) 736, 736, 740  B1P04810
736 NCR=1                B1P04820
      I1=4*NC1+K1            B1P04830
      KAD=4                 B1P04840
      NCX=NR1                B1P04850
      NCRV=1                B1P04860
      R1P04870
      IF (K1-4) 715, 714, 714  B1P04880
714 NEND=1               B1P04890
715 CONTINUE             B1P04900
      GO TO 725              B1P04910
740 CONTINUE             B1P04920
      IF (NSTP) 1000, 1000, 1001 B1P04930
1001 CONTINUE             B1P04940
      CALL RESET             B1P04950
      CALL CHAIN (2,2)         B1P04960
1000 CALL RFSET            B1P04970
      GO TO 21                B1P04980
      END                      B1P04990
      *                         B1P5000
      FORTRAN SUBROUTINE ADDM (X, Y, Z, M)

```

```

DIMENSION X(3600), Y(3600), Z(3600)
IF (M) 20,1,1
   DO 10 I=1,M
10  Z(I)= X(I)+Y(I)
11  GO TO 50
20  M=-M
DO 25 I=1,M
25  Z(I)= X(I)-Y(I)
50  RETURN
END
*          FORTRAN
SUBROUTINE ROUND
COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8
COMMON NDIM, NROW, NCOL, MM, I1, KP1, KP2, KM1, KM2, MFLAG, XM,
COMMON ISWI, ISW2, ISW3
COMMON A
COMMON TMP, YK, YL
DIMENSION MM(35)
DIMENSION A(1064)
DIMENSION TMP(5184), YK(5184), YL(4,4,324)
DIMENSION NN(3)
I1=I1
I1=0
NR1=NROW+1
NC1=NCOL+1
L=0
ITOT=3*(NROW+6)
L1=ITOT
CALL GRADE(1)
LL=KP2
CALL GRADE(NROW)
LL2=KM2
DO 460 I=1, NCOL
TP=TMP(L+15)
TP2=TMP(L1-12)
N1=L1
DO 458 K=3,5
N=K+L
CALL EXTRA ( TMP( N), TMP( N+3), TMP( N+6), TMP( N+9), TP)
B1P05020
B1P05030
B1P05040
B1P05050
B1P05060
B1P05070
B1P05080
B1P05090
B1P05100
B1P05110
B1P05120
B1P05130
B1P05140
B1P05150
B1P05160
B1P05170
B1P05180
B1P05190
B1P05200
B1P05210
B1P05220
B1P05230
B1P05240
B1P05250
B1P05260
B1P05270
B1P05280
B1P05290
B1P05300
B1P05310
B1P05320
B1P05330
B1P05340
B1P05350
B1P05360
B1P05370
B1P05380
B1P05390
B1P05400

```

```

CALL EXTRA ( TMP(N1), TMP(N1-3), TMP(N1-6), TMP(N1-9), TP2)
N1=K+L1-8
TP =TMP(N+13)
TP2=TMP(N1-12)
IF (LL) 453, 454, 454
453 TP=(TP+TMP(N+10))*5
454 IF (LL2) 458, 458, 456
456 TP2=(TP2+TMP(N1-9))*5
458 CONTINUE
L=L+ITOT
L1=L1+ITOT
460 CONTINUE
NN(1)=NC1*ITOT+7
NN(2)=NN(1)+1
NN(3)=NN(2)+ITOT+1
DO 515 J=1, NROW
DO 510 K=1, 3
N=NN(K)+3*j
N1=N-ITOT
N2=N1-ITOT
N3=N2-ITOT
N4=N3-ITOT
CALL EXTRA ( TMP(N), TMP(N1), TMP(N2), TMP(N3), TMP(N4))
510 CONTINUE
515 CONTINUE
L=NC1*ITOT
L1=L+4
LL=L1-2*ITOT
TMP(LL)=(TMP(LL)+TMP(LL+6))/2.
TMP(LL+1)=(TMP(LL+1)+TMP(LL+7))/2.
L1=L+ITOT-5
LL=L1-2*ITOT
TMP(LL)=(TMP(LL)+TMP(LL+6))/2.
TMP(LL+1)=(TMP(LL+1)+TMP(LL+5))/2.
RETURN
END
FORTRAN
SUBROUTINE CF(I, J, MF, K, AA, X)
COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8
B1P05410
B1P05420
B1P05430
B1P05440
B1P05450
B1P05460
B1P05470
B1P05480
B1P05490
B1P05500
B1P05510
B1P05520
B1P05530
B1P05540
B1P05550
B1P05560
B1P05570
B1P05580
B1P05590
B1P05600
B1P05610
B1P05620
B1P05630
B1P05640
B1P05650
B1P05660
B1P05670
B1P05680
B1P05690
B1P05700
B1P05710
B1P05720
B1P05730
B1P05740
B1P05750
B1P05760
B1P05770
B1P05780
B1P05790

```

```

DIMENSION X(72, 72)
COMMON NDIM, NROW, NCOL, MM, I1, KM1, KM2, KP1, KP2, MFLAG, XM, XLD
COMMON ISW1, ISW2, ISW3
COMMON A
COMMON TMP, YK, YL
DIMENSION MM(35)
DIMENSION A (1064)
DIMENSION AA(1140)
DIMENSION TMP (5184), YK(5184), YL(5184)
C COMPUTE COEFFICIENT OF KTH UNKNOWN FOR MESH PT I,J.
I2=1
J2=J
M=M†
J4=ISW1*38+1
NC1=NCOL+1
NR1=NROW+1
IF (ISW2) 107, 108, 108
107 FCTR=-1.
GO TO 109
108 FCTR=1.
109 IF (M) 110, 100, 120
110 IF (M+1) 111, 112, 112
111 J2=J2-1
M=0
GO TO 100
112 FCTR=FCTR/2.
J5=J2-1
GO TO 101
120 IF (M-1) 122, 122, 121
121 J2=J2+1
M=0
GO TO 100
122 FCTR=FCTR/2.
J5=J2+1
100 CONTINUE
101 IF (I2-1) 2, 4, 6
C COL 12 IS LEFT OF X-AXIS. REFLECT OVER SYMMETRY LINE. CHANGE SIGN
C IF K=2
2 I2=-I2+2
B1P05800
B1P05810
B1P05820
B1P05830
B1P05840
B1P05850
B1P05860
B1P05870
B1P05880
B1P05890
B1P05900
B1P05910
B1P05920
B1P05930
B1P05940
B1P05950
B1P05960
B1P05970
B1P05980
B1P05990
B1P06000
R1P06010
B1P06020
B1P06030
B1P06040
B1P06050
B1P06060
B1P06100
B1P06110
B1P06120
B1P06130
B1P06140
B1P06150
B1P06160
B1P06170
B1P06180

```

```

3 IF (K-2) 6, 3, 6
  GO TO 6
C   COL 12 IS X-AXIS. OMIT COEFFICIENT IF K=2
  4 IF (K-2) 6, 99, 6
  6 IF (J2-NR1) 14, 99, 7
  7 IF (J2-NR1-1) 8, 8, 11
  8 IF (K-2) 11, 11, 9
  9 IF (12-NC1) 10, 99, 11
C   COL J2 IS BEYOND THE BOUNDARY. K=3. SET J2=NROW-1
 10 J2=J2-2
    GO TO 50
 11 J2=NR1
 12 IF (12-NC1) 80, 99, 13
 13 I2=NC1
    GO TO 80
 14 CONTINUE
 19 IF (J2) 20, 99, 25
 20 IF (J2+1) 24, 21, 21
 21 IF (K-2) 24, 24, 22
 22 IF (12-NC1) 23, 99, 24
 23 J2=1
    GO TO 50
 24 J2=0
    GO TO 12
 25 IF (12-NC1) 50, 99, 26
 26 IF (12-NC1-1) 27, 27, 13
 27 IF (K-2) 13, 13, 28
 28 I2=I2-2
 50 J1=INDX(I2, J2, K)
  IF (MFLAG) 51, 51, 52
 51 X(I1, J1)=X(I1, J1)+AA(J4)*FCTR
 125 IF (M) 130, 99, 130
 52 YK(I1+2970)=YK(I1+2970)-AA(J4)*FCTR*TMP(J1)
    GO TO 125
 80 J1=INDX(I2, J2, K)
  J3=(J1+5-I1)*270+11
  YK(J3)=YK(J3)+AA(J4)*FCTR
  IF (M) 135, 99, 135

```

```

99 RETURN
130 J2=J5
M=0
GO TO 50
135 J2=J5
M=0
GO TO 80
END
*          FORTRAN      CFZ( J, AA )
FUNCTION CFZ( J, AA )
COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8
COMMON NDIM, NROW, NCOL, MM, MFLAG, XM,XLD
DIMENSION MM(40), AA(1)
J1=J*38+1
CFZ=AA(J1)
RETURN
END
*          FORTRAN      SUROUTINE COEFFZ
SUBROUTINE COEFFZ
COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8
COMMON NDIM, NROW, NCOL, MM, MFLAG, XM,XLD
COMMON ISWI, ISW2, ISW3
COMMON A, A1, A2, A3, A4, A5, A6, A7, A8
COMMON B, B1, B2, B3, B4, B5, B6, B7, B8, B9, B10
COMMON C, C1, C2, C3, C4, C5, C6, C7, C8,C9, C10,C11,C12,C13,C14,
1 C15, C16, C17
COMMON FILL
COMMON TMP, YK, YL
COMMON T1, T2, XX, XX1, Z, Z1, Z2
COMMON ZNU, THC, HBO, H1, X0XL, PH3, PH2, XXH, XR
DIMENSION TMP (5184), YK(5184), YL(5184)
DIMENSION T1( 89), T2(89), XX(89), XX1(89), Z(89), Z1(89), Z2(89)
DIMENSION MM(40)
DIMENSION A(1)
NR1=NROW+1
DIMENSION FILL (1026)
SNP3= SINF(PH3)
CSP3= COSF(PH3)
TNP3= SNP3/CSP3
B1P06580
B1P06590
B1P06600
B1P06610
B1P06620
B1P06630
B1P06640
B1P06650
B1P06660
B1P06670
B1P06680
B1P06690
B1P06700
B1P06710
B1P06720
B1P06730
B1P06740
B1P06750
B1P06760
B1P06770
B1P06780
B1P06790
B1P06800
B1P06810
B1P06820
B1P06830
B1P06840
B1P06850
B1P06860
B1P06870
B1P06880
B1P06890
B1P06900
B1P06910
B1P06920
B1P06930
B1P06940
B1P06950
B1P06960

```

```

CTP3= CSP3/SNP3
D1=H1*ZNU
D2=(1.-ZNU)
D3=THC*SNP3
E2=-D2/(2.*D3*D3)
E5=-(1.+ZNU)/(2.*D3)
E61=(3.-ZNU)/(2.*D3)
E62=-D1/D3
E7 = -ZNU*CTP3
F1= E5/2.
F21=-F61
F22=-D2*H1/(2.*D3)
F31= -D2/2.
F32= F31/(3.*TNP3***2)
F41= 1./(D3*D3)
F42= F41/(12.*TNP3***2)
F51= F31
F52=-1./(3.*TNP3***2)
F53= H1/TNP3***2
F7= (2.-ZNU)*CTP3/(12.*D3)
F81= CTP3/(12.*D3***3)
F91= CTP3*(1.-2.*ZNU)/(12.*D3)
F92= F31*CTP3*H1/D3
F101= CTP3/D3
F102= F101*D2/6.
F103= F92
G1=ZNU*CTP3
G3=-(2.-ZNU)/12.*CTP3/D5
G4=-CTP3/(12.*D3***3)
G51= CTP3/(4.*D3)
G52= -2.*H1*G51
G61=CTP3/D3
G62= -3.*G61*H1/4.
G63= ZNU*H1*H1*G61/2.
G8= 1./(6.*D3***2)
G9= 1./((12.*D3***4)
G10=H1/2.
G111= -G8
G112= H1/(2.*D3***2)

```

```

G121= (2.+ZNU)*H1/4.
G122= H1*H1/2.
G131= 1./(3.*D3*D3)
G132= -3.*H1/(4.*D3*D3)
G133= ZNU*H1*H1/(2.*D3*D3)
G141=-H1/4.
G142= ZNU*H1*H1/2.
G15 = CTP3***2
DO 60 JJ=0, NR1
J=NR1-JJ
IF (J) 55, 55, 54
54 XH=XXH/2.*MM(J)
55 X=YK(J)
HB=HBO+H1*X
X3=HB/X
F8=F81/X
A1=-HB/XH**2-(X3+H1)/(2.*XH)
A2=-HB/XH**2+(X3+H1)/(2.*XH)
A3= E2*X3/X/XK**2
A4= -(A1+A2)-2.*A3+(X3-D1)/X
A5= E5*X3/(4.*XH*XK)
A6= (E61*X3+E62)/(2.*X*XK)
A7= E7*X3/(2.*XH)
A8= CTP3*(X3-D1)/X
B1=A5
B2= (F21*X3+F22)/(2.*X*XK)
B3=(F31+F32*X3*X3)*HB/XH**2
D4= F31*(X3+H1+F52*X3**3+F53*X3**2)
B4=B3-D4/(2.*XH)
B3=B3+D4/(2.*XH)
B5=(F41+F42*X3**2)*X3/(X*XK*XK)
B5=-B5
B6=-(B3+B4)-2.*B5-D4/X
D4= F7*HB*X3**2/(XH*XH*XK)
B7=-D4-F8*(X3/XK)**3+F101*X3*(-1.+D2/6.*X3*(X3-3.*H1))/(2.*XK)/X
B9=-(F91*X3**3+F92*X3**2)/(4.*XH*XK)
B8= D4/2.+B9
B9= D4/2.-B9
B10= F8/2.*((X3/XK)**3
R1P07360
B1P07370
B1P07380
B1P07390
B1P07400
B1P07410
B1P07420
B1P07430
B1P07440
B1P07450
B1P07460
B1P07470
B1P07480
B1P07490
B1P07500
B1P07510
B1P07520
B1P07530
B1P07540
B1P07550
B1P07560
B1P07570
B1P07580
B1P07590
B1P07600
B1P07610
B1P07620
B1P07630
B1P07640
B1P07650
B1P07660
B1P07670
B1P07680
B1P07690
B1P07700
B1P07710
B1P07720
B1P07730
B1P07740

```

```

C1=-A7
C2=CTP3*X3/X
D4= (G3*HB*X3**2)/(XH*XH*XK)
D5= G4*(X3/XK)**3/X
D6= (G61+G61*X3**2/3.+G62*X3+G63)*X3/(2.*X*XK)
C3=-D4+D5+D6
C4=D4+3.*D5-D6
D6= (G51*X3+G52)*X3**2/(4.*XH*XK)
C5= D4/2.+D6
C6= D4/2.-D6
C7= -D5
C8= -3.*D5
D4= HB**3/(12.*XH**4)
D6= (X3/6.+G10)*HB*HR/XH**3
D5= G8*HB*X3**2/(XH*XK)**2
D7= (G112-G8*X3)*X3**2/(XH*XK*XK)
D8= (G121*X3-X3**2/12.+G122)*HB/XH**2
D10= (G131*X3**2+G132*X3+G133)*X3/(Y*XK**2)
C9=D4+D6/2.
C10=D4-D6/2.
C11= G9*X3**3/(X*XK**4)
C14= (X3*X3/12.+G141*X3+G142)*X3/(2.*XH)
C12=-4.*D4-2.*D5-D6-D7+D8+C14
C13=-4.*D4-2.*D5+D6+D7+D8-C14
C14=-2.*D5-4.*C11+D10
C15= D5+D7/2.
C16= D5-D7/2.
C17=6.*((D4+C11)+4.*D5-2.*D8-2.*D10+G15*X3/X
A=1.
B=1.
C=1.
CALL NORM (A1, A, 8)
CALL NORM (B1, B, 10)
CALL NORM (C1, C, 17)
DO 58 L=1, 38
L1=J*38+L
58 A(L1)=A(L)
60 CONTINUE
RETURN
B1P07750
B1P07760
B1P07770
B1P07780
B1P07790
B1P07800
B1P07810
B1P07820
B1P07830
B1P07840
B1P07850
B1P07860
B1P07870
B1P07880
B1P07890
B1P07900
B1P07910
B1P07920
B1P07930
B1P07940
B1P07950
B1P07960
B1P07970
B1P07980
B1P07990
B1P08000
B1P08010
B1P08020
B1P08030
B1P08040
B1P08050
B1P08060
B1P08070
B1P08080
B1P08090
B1P08100
B1P08110
B1P08120
B1P08130

```

```

      *
      END
      FORTRAN
      * SURROUNTE CONS (X, I)
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8
      COMMON NDIM, NROW, NCOL, MM, MFLAG, XM, XLD
      COMMON TSW1, TSW2, TSW3
      COMMON A, A1, A2, A3, A4, A5, A6, A7, A8
      COMMON B, B1, B2, B3, B4, B5, B6, B7, B8, B9, B10
      COMMON C, C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14,
      1 C15, C16, C17
      COMMON FILL
      COMMON TMP, YK, YL
      COMMON T1, T2, XX, XX1, Z, Z1, Z2
      COMMON ZNU, THC, HBO, H1, X0XL, PH2, XH, XK
      COMMON ZETA
      COMMON TE, TI, TO, OC, TC, TD, DDLD
      DIMENSION T1( 89), T2( 89), XX( 89), XX1( 89), Z( 89), Z1( 89),
      DIMENSION TMP( 5184), YK( 5184), YL( 5184)
      DIMENSION ZETA( 30)
      DIMENSION MM(40)
      DIMENSION X(72), A(1), B(1), C(1)
      DIMENSION FILL(1026)
      3 DO 5 J=1, NDIM
      5 X(J)=0*
      6 IF (IOPT2-1) 6,20,21
      6 DO 10 J=1, NROW
      11=INDX(I, J, 3)
      J4=J*38+1
      10 X(I1)=C(J4)
      GO TO 99
      20 SP3=SINF(PH3)
      CP3=COSF(PH3)
      STC=SINF(THC)
      CTC=COSF(THC)
      SP2=SINF(PH2)
      CP2=COSF(PH2)
      FCTR=1-1
      ETA=FCTR*XK
      DO 30 J=1, NROW
      R1P08140
      B1P08150
      R1P08160
      B1P08170
      B1P08180
      B1P08190
      B1P08200
      B1P08210
      B1P08220
      B1P08230
      B1P08240
      B1P08250
      B1P08260
      B1P08270
      B1P08280
      B1P08290
      B1P08300
      B1P08310
      B1P08320
      B1P08330
      B1P08340
      B1P08350
      B1P08360
      B1P08370
      B1P08380
      B1P08390
      B1P08400
      B1P08410
      B1P08420
      B1P08430
      B1P08440
      B1P08450
      B1P08460
      B1P08470
      B1P08480
      B1P08490
      R1P08500
      B1P08510
      R1P08520

```

```

J4=J*38+1
I1=INDX(I,J,1)
X(I1)=A(J4)*(CP2*CP3-SP3*SP2*CTC*ETA)
IF (I-1) 24, 23
23 I1=INDX(I,J,2)
      X(I1)=B(J4)*SP2*STC*ETA
24 I1=INDX(I,J,3)
      X(I1)=-C(J4)*(SP3*CP2+SP2*CP3*CTC*ETA)
30 CONTINUE
GO TO 99
21 CONTINUE
DO 31 J = 1, NROW
J4 = J*38 +1
I1 = INDX(I,J,1)
X(I1) = A(J4)* TC *H1
I1 = INDX(I,J,3)
X(I1) = C(J4)*(-TD*H1*H1/6.+ (HBO/ZETA(J+1) +H1)*(TC-TD*H1))
31 CONTINUE
99 RETURN
END
*          FORTRAN
FUNCTION DEF (II, JJ, KK, MF)
COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8
COMMON NDIM, NROW, NCOL, MM, MFLAG, XM,XLD
COMMON ISW1, ISW2, ISW3
COMMON A
COMMON TMP, YK, YL
DIMENSION MM(40)
DIMENSION A (1064)
DIMENSION TMP (5184), YK(5184), YL(5184)
N2=3*(NROW+6)
I=II
J=JJ
K=KK
M=MF
IF (M) 60, 50, 70
60 IF (M+1) 61, 62, 62
61 J=J-1
M=0

```

```

GO TO 50
B1P08920
B1P08930
B1P08940
B1P08950
B1P08960
B1P08970
B1P08980
R1P08990
R1P09000
B1P09010
B1P09020
B1P09030
B1P09040
B1P09050
B1P09060
B1P09070
B1P09080
R1P09090
B1P09100
R1P09110
B1P09120
B1P09130
B1P09140
B1P09150
B1P09160
B1P09170
B1P09180
B1P09190
B1P09200
B1P09210
B1P09220
B1P09230
B1P09240
B1P09250
R1P09260
B1P09270
B1P09280
B1P09290
B1P09300

62 J2=J-1
GO TO 50
B1P08930
B1P08940
B1P08950
B1P08960
B1P08970
B1P08980
R1P08990
R1P09000
B1P09010
B1P09020
B1P09030
B1P09040
B1P09050
B1P09060
B1P09070
B1P09080
R1P09090
B1P09100
R1P09110
B1P09120
B1P09130
B1P09140
B1P09150
B1P09160
B1P09170
B1P09180
B1P09190
B1P09200
B1P09210
B1P09220
B1P09230
B1P09240
B1P09250
R1P09260
B1P09270
B1P09280
B1P09290
B1P09300

70 IF (M-1) 72, 72, 71
71 J=J+1
M=0
GO TO 50
B1P08920
B1P08930
B1P08940
B1P08950
B1P08960
B1P08970
B1P08980
R1P08990
R1P09000
B1P09010
B1P09020
B1P09030
B1P09040
B1P09050
B1P09060
B1P09070
B1P09080
R1P09090
B1P09100
R1P09110
B1P09120
B1P09130
B1P09140
B1P09150
B1P09160
B1P09170
B1P09180
B1P09190
B1P09200
B1P09210
B1P09220
B1P09230
B1P09240
B1P09250
R1P09260
B1P09270
B1P09280
B1P09290
B1P09300

50 SIGN=1.
IF (I-1) 1, 5, 5
1 I=2-1
IF (K-2) 5, 2, 5
2 SIGN=-1.
5 I2=(I-1)*N2+3*j+k+6
IF (M) 16, 13, 16
13 IF (SIGN) 14, 15, 15
14 DEF=-TMP(I2)
GO TO 99
B1P08920
B1P08930
B1P08940
B1P08950
B1P08960
B1P08970
B1P08980
R1P08990
R1P09000
B1P09010
B1P09020
B1P09030
B1P09040
B1P09050
B1P09060
B1P09070
B1P09080
R1P09090
B1P09100
R1P09110
B1P09120
B1P09130
B1P09140
B1P09150
B1P09160
B1P09170
B1P09180
B1P09190
B1P09200
B1P09210
B1P09220
B1P09230
B1P09240
B1P09250
R1P09260
B1P09270
B1P09280
B1P09290
B1P09300

16 I3=(I-1)*N2+3*j2+k+6
DEF=SIGN*(TMP(I2)+TMP(I3))/2.
99 RETURN
END

* FORTRAN
* SUBROUTINE EQ1 (X, I11, I1, JJ, MX)
C COMPUTE COEFFICIENTS FOR EQUATION ONE FOR MESH PT I,J
COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8
COMMON NDIM, NROW, NCOL, MM, KO, KM1, KM2, KP1, KP2, MFLAG, XM, XLD
COMMON ISW1, ISW2, ISW3
COMMON A, A1, A2, A3, A4, A5, A6, A7, A8
DIMENSION MM(35)
I1=I11
I=I1
J=JJ
M=MX
GO TO (30, 20, 30, 40, 50), M
20 CONTINUE
MF=0

```

```

I SW2=0          R1P09310
CALL CF ( I-1, J, MF, 1, A3, X)    B1P09320
I SW2=-1         R1P09330
CALL CF ( I-1, J, MF,2, A6, X)    R1P09340
MF=KM1           B1P09350
CALL CF ( I-1, J-1, MF, 2, A5,X)  R1P09360
MF=KP1           B1P09370
I SW2=0          B1P09380
CALL CF ( I-1, J+1, MF, 2, A5,X)  B1P09390
GO TO 50         B1P09400
CONTINUE         B1P09410
I SW2=0          B1P09420
MF=0             B1P09430
CALL CF ( I, J, MF, 1, A4,X)      B1P09440
CALL CF ( I, J, MF, 3, A8, X)      B1P09450
MF=KM1           B1P09460
CALL CF ( I, J-1, MF, 1, A1, X)    B1P09470
CALL CF ( I, J-1, MF, 3, A7, X)    B1P09480
MF=KP1           B1P09490
CALL CF ( I, J+1, MF, 1, A2, X)    B1P09500
I SW2=-1         B1P09510
CALL CF ( I, J+1, MF, 3, A7, X)    B1P09520
IF (MFLAG) 50, 50, 40              B1P09530
CONTINUE         B1P09540
MF=0             B1P09550
I SW2=0          R1P09560
CALL CF ( I+1, J, MF, 1, A3, X)    B1P09570
CALL CF ( I+1, J, MF,2, A6,X)     R1P09580
MF=KM1           R1P09590
CALL CF ( I+1, J-1, MF, 2, A5,X)  B1P09600
MF=KP1           B1P09610
I SW2=-1         R1P09620
CALL CF ( I+1, J+1, MF, 2, A5,X)  B1P09630
45 IF (I-1) 20, 20, 46            B1P09640
46 IF (MFLAG) 50, 50, 20          B1P09650
50 RETURN         B1P09660
END              B1P09670
FORTRAN         B1P09680
SUBROUTINE FQ2 (X, III, II, JJ, MX)

```

*

```

C COMPUTE EQUATION TWO FOR MFSH PT I, J.
COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8
COMMON NDIM, NROW, NCOL, MM, K0, KM1, KM2, KP1, KP2, MFLAG, XM, XLD
COMMON ISW1, ISW2, ISW3
COMMON A, A1, A2, A3, A4, A5, A6, A7, A8
COMMON B, B1, B2, B3, B4, B5, B6, B7, B8, B9, B10
DIMENSION MM(35)
I1=111
I=11
J=JJ
M=MX
GO TO 30, 20, 30, 40, 501, M
20 CONTINUE
  ISW2=0
  MF=0
  CALL CF ( I-1, J, MF, 2, B5, X)
  ISW2=-1
  CALL CF ( I-1, J, MF, 1, B2, X)
  CALL CF ( I-1, J, MF, 3, B7, X)
  MF=KM1
  CALL CF ( I-1, J-1, MF, 1, B1, X)
  CALL CF ( I-1, J-1, MF, 3, B8, X)
  MF=KP1
  CALL CF ( I-1, J+1, MF, 3, B9, X)
  ISW2=0
  CALL CF ( I-1, J+1, MF, 1, B1, X)
  GO TO 50
30 CONTINUE
  ISW2=0
  MF=KM1
  CALL CF ( I, J-1, MF, 2, B3, X)
  MF=KP1
  CALL CF ( I, J+1, MF, 2, B4, X)
  MF=0
  CALL CF ( I, J, MF, 2, B6, X)
33 IF (MFLAG) 34, 34, 35
34 IF (I-2) 50, 35, 36
35 CONTINUE
  ISW2=-1

```

```

CALL CF ( I-2, J, MF, 3, B10, X)
IF (MFLAG) 50, 50, 37
36 IF (I-NCOL) 50, 37, 37
37 CONTINUE
ISW2=0
CALL CF ( I+2, J, MF, 3, B10, X)
IF (MFLAG) 50, 50, 40
40 CONTINUE
ISW2=0
MF=0
CALL CF ( I+1, J, MF, 1, B2,X)
CALL CF ( I+1, J, MF, 2, B5,X)
CALL CF ( I+1, J, MF, 3, B7,X)
MF=KM1
CALL CF ( I+1, J-1, MF, 1, B1,X)
CALL CF ( I+1, J-1, MF, 3, B8,X)
MF=KP1
CALL CF ( I+1, J+1, MF, 3, B9,X)
ISW2=-1
CALL CF ( I+1, J+1, MF, 1, B1,X)
45 IF (I-1) 20, 20, 46
46 IF (MFLAG) 50, 50, 20
50 RETURN
END
*          FORTRAN
*          SUBROUTINE EQ3 (X,II,JJ,MX)
*          COMPUTE EQUATION THREE FOR MESH PT I,J.
C           DIMENSION MM(35)
COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8
COMMON NDIM, NROW, NCOL, MM, KO, KM2, KP1, KP2, MFLAG, XM, XLD
COMMON ISW1, ISW2, ISW3
COMMON A, A1, A2, A3, A4, A5, A6, A7, A8
COMMON R, R1, R2, R3, R4, R5, R6, R7, R8, R9, R10
COMMON C, C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14,
1 C15, C16, C17
I1=II
I=II
J=JJ
M=MX
B1P10090
B1P10100
B1P10110
B1P10120
B1P10130
B1P10140
B1P10150
B1P10160
R1P10170
R1P10180
B1P10190
B1P10200
B1P10210
B1P10220
B1P10230
B1P10240
B1P10250
B1P10260
B1P10270
B1P10280
B1P10290
B1P10300
B1P10310
R1P10320
B1P10330
B1P10340
B1P10350
B1P10360
B1P10370
B1P10380
B1P10390
R1P10400
R1P10410
R1P10420
R1P10430
B1P10440
R1P10450
B1P10460
B1P10470

```

```

GO TO (30, 20, 30, 40, 50), M
20 CONTINUE
 1 SW2=0
MF=0      R1P10480
CALL CF ( I-1, J, MF, 2, C4, X)    B1P10490
CALL CF ( I-1, J, MF, 3, C14, X)    B1P10510
MF=KM1     B1P10520
CALL CF ( I-1, J-1, MF, 3, C15, X)    B1P10530
1 SW2=-1    B1P10540
CALL CF ( I-1, J-1, MF, 2, C5, X)    B1P10550
MF=KP1     B1P10560
CALL CF ( I-1, J+1, MF, 2, C6, X)    B1P10570
1 SW2=0    B1P10580
CALL CF ( I-1, J+1, MF, 3, C16, X)    B1P10590
B1P10600
CALL CF ( I-1, J+1, MF, 3, C16, X)    B1P10610
GO TO 50   B1P10620
B1P10630
B1P10640
B1P10650
B1P10660
B1P10670
B1P10680
B1P10690
B1P10700
B1P10710
B1P10720
B1P10730
B1P10740
B1P10750
B1P10760
B1P10770
B1P10780
B1P10790
B1P10800
B1P10810
B1P10820
B1P10830
B1P10840
B1P10850
R1P10860

30 CONTINUF
 1 SW2=0
MF=KM1
CALL CF ( I, J-1, MF, 1, C1, X)
CALL CF ( I, J-1, MF, 3, C12, X)
MF=KP1
CALL CF ( I, J+1, MF, 3, C13, X)
1 SW2=-1
CALL CF ( I, J+1, MF, 1, C1, X)
MF=KM2
1 SW2=0
CALL CF ( I, J-2, MF, 3, C9, X)
MF=KP2
CALL CF ( I, J+2, MF, 3, C10, X)
MF=0
CALL CF ( I, J, MF, 1, C2, X)
CALL CF ( I, J, MF, 2, C8, X)
CALL CF ( I, J, MF, 3, C17, X)
37 IF (MFLAG) 36, 36, 38
36 IF (I-2) 50, 38, 39
38 CONTINUE
CALL CF ( I-2, J, MF, 2, C7, X)
CALL CF ( I-2, J, MF, 3, C11, X)
IF (MFLAG) 50, 50, 390

```

```

39 IF (I-NCOLL) 50, 390, 390
390 CONTINUE
CALL CF ( I+2, J, MF, 3, C11, X)
IF (MFLAG) 50, 50, 40
40 CONTINUE
MF=0
ISW2=0
CALL CF ( I+1, J, MF, 2, C3, X)
CALL CF ( I+1, J, MF, 3, C14, X)
MF=KM1
CALL CF ( I+1, J-1, MF, 2, C5, X)
CALL CF ( I+1, J-1, MF, 3, C15, X)
MF=KP1
CALL CF ( I+1, J+1, MF, 2, C6, X)
CALL CF ( I+1, J+1, MF, 3, C16, X)
45 IF (I-1) 20, 20, 46
46 IF (MFLAG) 50, 50, 20
50 RETURN
END
*
FORTRAN
SUBROUTINE FXTRA (X, X1, X2, X3, X4)
X=4.*X1-6.*X2+4.*X3-X4
RETURN
END
*
FORTRAN
SUBROUTINE GRADE (J)
COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8
COMMON NDIM, NROW, NCOL, MM, KO, KM1, KM2, KP1, KP2, MFLAG, XM, XLD
DIMENSION MM(35)
DO 2 I=37, 40
2 MM(I)=0
1 IF (J) 99, 99, 1
1 JM=MM(J)
JM1=MM(J-1)
JM2=MM(J-2)
JP1=MM(J+1)
JP2=MM(J+2)
IF (J-2) 10, 10, 4
4 IF (J-NROW+1) 5, 30, 30

```

```

      5 IF (JP2-JM2) 10, 20, 30
      C MESH SPACING INCREASING
     10 IF (JP1-JM) 11, 12, 12
      C DOUBLE MESH SPACING AFTER THIS ROW
     11 KP1=-1
        KP2=-2
          IF (J-1) 40, 40, 99
        12 IF (JP2-JP1) 14, 18, 18
     14 KP2=-1
        IF (J-2) 40, 15, 15
      15 IF (JM-JM1) 16, 99, 99
      C MESH SPACING CHANGES IN BOTH DIRECTIONS
     16 KM2=-2
        GO TO 40
      18 IF (J-2) 40, 20, 13
      13 IF (JM-JM1) 19, 20, 20
      C DOUBLE THE MESH SPACING
     19 KM2=-2
        GO TO 40
      20 GO TO 99
      C MESH SPACING IS DECREASING
     30 IF (JM-JM1) 32, 32, 31
      C CUT MESH SPACING IN HALF
     31 KM1=1
        KM2=2
        GO TO 40
      32 IF (JM1-JM2) 37, 37, 33
      33 IF (J-NROW+1) 35, 34, 34
      C MESH SPACING AT LAST ROW WAS CUT IN HALF
     34 KM2=1
        GO TO 99
      35 IF (JP1-JM) 34, 34, 36
      C SPACING CHANGES IN BOTH DIRECTIONS
     36 KM2=1
        KP2=2
        GO TO 99
      37 IF (J-NROW+1) 38, 20, 20
      38 IF (JP1-JM) 20, 20, 39
      C MESH CUT IN HALF AFTER NEXT ROW

```

```

39 KP7=7      R1P11650
40 GO TO 99    B1P11660
40 CONTINUE    R1P11670
99 RETURN     B1P11680
END          R1P11690
*           R1P11700
        FUNCTION INDX(II, JJ, KK)
COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8
COMMON NDIM, NROW, NCOL, MM, MFLAG, XM, XLD
DIMENSION MM(40)      B1P11720
II=II          B1P11730
JJ=JJ          B1P11740
KK=KK          B1P11750
IF (MFLAG) 100, 100, 200      B1P11760
CONTINUE      R1P11770
20 IF (I-1) 21, 21, 29      B1P11780
21 IF (K-1) 22, 22, 24      B1P11790
22 INDX=J*2-1      B1P11800
GO TO 50      B1P11810
24 INDX=J*2      B1P11820
GO TO 50      B1P11830
29 INDX=3*K-3      B1P11840
GO TO 50      B1P11850
      B1P11860
      B1P11870
100 IF (I-NCOL) 201, 201, 220      R1P11880
200 IF (J-NROW) 202, 202, 210      R1P11890
201 IF (J) 230, 230, 205      B1P11900
202 IF (I-1)*(NROW+6)*3+3*K+6      B1P11910
205 INDX=      R1P11920
GO TO 50      B1P11930
210 INDX=3*( NROW+NCOL+NCOL-I ) +K+5      B1P11940
211 IF (I-1) 214, 214, 50      B1P11950
212 IF (K-2) 50, 50, 215      B1P11960
215 INDX=INDX-1      B1P11970
GO TO 50      B1P11980
220 INDX=3*K-4      B1P11990
221 INDX=INDX+3*NCOL+3      R1P12000
GO TO 50      B1P12010
230 INDX=3*I+K-4      R1P12020
231 IF (I-1) 231, 231, 50      R1P12030

```

```

B1P12040
B1P12050
B1P12060
B1P12070
B1P12080
B1P12090
B1P12100
B1P12110
B1P12120
B1P12130
B1P12140
R1P12150
B1P12160
R1P12170
R1P12180
B1P12190
B1P12200
B1P12210
R1P12220
B1P12230
B1P12240
R1P12250
B1P12260
B1P12270
R1P12280
R1P12290
B1P12300
B1P12310
B1P12320
B1P12330
B1P12340
B1P12350
R1P12360
B1P12370
B1P12380
B1P12390
B1P12400
B1P12410
B1P12420

232 INDEX=INDEX+1
50 RETURN
END
*
FORTRAN
SUBROUTINE INVERT(A,IMAX,ISING)
C
SUBROUTINE TO INVERT A MATRIX
DIMENSION A(72, 72), IN(72),'TEMP(72)
ISING=0
N=IMAX
IMAXO=N-1
I1=1
1 I3=I1
IN(I1)=0
SUM=ABSF(A(I1,I1))
DO3I=11,N
IF((SUM-ABSF(A(I,I1)))/2,3,3
2 I3=I
IN(I1)=I
SUM=ABSF(A(I,I1))
3 CONTINUE
IF((I3-I1)/4,6,4
4 DO5J=1,N
SUM=A(I1,J)
A(I1,J)=A(I3,J)
5 A(I3,J)=SUM
6 I3=I1+1
IF(A(I1,I1))97,99,97
97 DO7I=I3,N
7 A(I,I1)=A(I,I1)/A(I1,I1)
J2=I1-1
IF(J2)8,11,8
8 DO9J=I3,N
9 A(I1,J)=A(I1,J)-DPSUM (A,I1,J,1,J2)
11 J2=I1
I1=I1+1
DO12I=I1,N
12 A(I,I1)=A(I,I1)-DPSUM(A, I, I1, 1, J2)
14 DO600JP=1,N

```

```

J=N+1-JP
A(I,J)=1.0/A(J,J)
IF(J-1)603,700,603
603 D06001P=2,J
I=J+1-IP
IPO=1+1
SUM=-DPSUM (A,I,J,IPO,J)
600 A(I,J)=SUM/A(I,I)
700 D0151J=1,IMAXN
JPO=J+1
D0151I=JPO,N
IMO=I-1
SUM=-DPSUM (A,I,J,J+1,IMO)
SUM=SUM-A(I,J)
151 A(I,J)=SUM
D0901I=1,N
D0900J=1,N
IF (I-J) 897,897,898
897 TEMP(J)=DPSUM(A,I,J,J+1,N)
TFMP(J)=TEMP(J)+A(I,J)
GO TO 900
898 TEMP(J)=DPSUM(A,I,J,I,N)
900 CONTINUE
D0901J=1,N
901 A(I,J)=TEMP(J)
D0500I=2,N
M=N+1-I
IF(IN(M))502,500,502
502 ISS=IN(M)
D0503L=1,N
SUM=A(L,ISS)
A(L,TSS)=A(L,M)
503 A(L,M)=SUM
500 CONTINUE
GO TO 805
99 ISING=1
805 RETURN
END
FORTRAN

```

*

```

SUBROUTINE MTX (X, I, M)
COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8
COMMON NDIM, NROW, NCOL, MM, II, KM1, KM2, KP1, KP2, MFLAG, XM, XLD
COMMON ISW1, ISW2, ISW3
DIMENSION MM(35)
DIMENSION X(72, 72)

I1=0
DO 1 I1=1, NDIM
DO 1 JU=1, NDIM
1 X(I1, JU)=0.
DO 100 J=1, NROW
ISW1=J
IF (XM) 50, 50, 7
7 CALL GRADE (J)
50 CONTINUE
58 I1=I1+1
CALL EQ1 (X, II, I, J, M)
59 IF (I-1) 61, 61, 60
60 I1=I1+1
CALL EQ2 (X, II, I, J, M)
61 I1=I1+1
CALL EQ3 ( X, II, I, J, M)
100 CONTINUE
RETURN
END

* * *
FORTRAN
LIST
SUBROUTINE MTXS (X, Y, II, M)
COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8
COMMON NDIM, NROW, NCOL, MM, MFLAG, XM, XLD
COMMON ISW1, ISW2, ISW3
COMMON A, A1, A2, A3, A4, A5, A6, A7, A8
COMMON B, B1, B2, B3, B4, B5, B6, B7, B8, B9, B10
COMMON C, C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14,
1 C15, C16, C17
COMMON FILL
DIMENSION FILL (1026)
DIMENSION MM(40)

```

```

C      MULTIPLICATION BY A SINGLE DIAGONAL
      DIMENSION X(72, 72), Y(72, 72)
      I=II
      3 IF (M-1) 20, 100, 100
      C      CLEAR OUT Y
      20 DO 23 J=1, NDIM
      23 Y(J,1)=0.
      L1=1
      GO TO 2
100  L1=NDIM
      IF (M-1) 202,50
      C      FORM A*X AND STORE IN Y
      2 DO 5 J=1,NROW
      6 CONTINUE
      7 I1=INDX (I, J, 2)
      I2=I1+1
      J1=INDX (I-2, J, 3)
      J2=J1-1
      IF (I-3) 31, 31, 32
      31 CC=0.
      GO TO 33
      32 CC=CFZ (J, C7)
      33 BB=CFZ (J, B10)
      CC2=CFZ (J, C11)
      DO 4 K=1, L1
      Y(I1, K)=Y(I1, K)-X( J1, K)*RR
      4 Y(I2, K)=Y(I2, K)+X (J2, K)*CC+X (J1, K)*CC2
      5 CONTINUE
      GO TO 99
      C      FORM X*X AND STORE IN Y
      50 CONTINUE
      DO 60 J=1, NROW
      51 CONTINUE
      52 IF (I-1) 49, 49, 48
      49 CC=2.*CFZ (J, C11)
      BB=0.
      GO TO 57
      48 CC=CFZ (J, C11)
      BB= CFZ (J, B10)

```

```

57 I2= INDX (I, J, 3)
CC2= CFZ (J, C7)
I1=I2-1
J1= INDX(I+2, J, 2)
J2=J1+1
IF (I-1) 53, 53, 55
53 DO 54 K=1, L1
54 Y(K, J1)=Y(K, J1)-X(K, I2)*CC2
55 DO 58 K=1, L1
58 Y(K, J2)= Y(K, J2)+X(K, I1)*BB+X(K, I2)*CC
60 CONTINUE
60 RETURN
99 RETURN
END
* FORTRAN
SUBROUTINE NORM (X, CONS, K)
DIMENSION X(17), Y(17)
DO 1 I=1,K
1 Y(I)=ABSF(X(I))
DO 10 I=2,K
10 F(Y(I)-Y(I)) 2,10,10
2 TEMP=Y(1)
Y(1)=Y(I)
Y(I)=TEMP
10 CONTINUE
DO 20 I=1,K
20 X(I)=X(I)/Y
CONS=CONS/Y
RETURN
END
* FORTRAN
SUBROUTINE STORE (X, II)
DIMENSION MM(40)
COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IC, TT, IOPT8
COMMON NDIM, NROW, NCOL, MM, MFLAG, XM, XLD
COMMON ISWI, ISW2, ISW3
COMMON A
COMMON TMP, YK, YL
DIMENSION TMP (5184), YK(5184), YL(5184)
DIMENSION A (1064)

```

```

DIMENSION X(59)
N2= (NROW+6)*3
NC1=NCOL+1
IF (MFLAG) 100, 100, 201
100 N1=(I1-1)*N2+10
I2=0
DO 110 J=1, NROW
103 I2=I2+1
    TMP(N1)=X(I2)
104 IF (IT-1) 107, 107, 106
106 I2=I2+1
    TMP(N1+1)=X(I2)
107 I2=I2+1
    TMP(N1+2)=X(I2)
110 N1=N1+3
    GO TO 999
?01 I2=11*?70
DO 210 I=1, NCOL
N1= (I-1)*N2+1
I2=I2+1
    TMP(N1+3)=YK(I2)
    IF (I-1) 208, 208, 204
204 I2=I2+1
    TMP(N1+4)=YK(I2)
208 I2=I2+1
    TMP(N1+2)=YK(I2)
    TMP(N1+5)=TMP(N1+11)
210 CONTINUE
N1=NC1*N2+4
    TMP(N1)=YK(I2+1)
    TMP(N1+1)=YK(I2+2)
    TMP(N1+2)=YK(I2+3)
    TMP(N1+6)=YK(I2+4)
    I2=I2+4
    GO TO 222
222 NO=NC1*N2+10
N1=NO+N2
NN=NO-N2-N2
    TMP(NO+1)=YK(I2+1)

```

```

      TMP(N1+2)=YK(I2+2)
      I2=I2+2
      TMP(N0+2)=TMP(NN+2)
      DO 240 J=2, NROW
      N0=N0+3
      N1=N1+3
      NN=NN+3
      TMP(N0)=YK(I2+1)
      TMP(N0+1)=YK(I2+2)
      TMP(N0+2)=TMP(NN+2)
      TMP(N1+2)=YK(I2+3)
240   I2=I2+3
      N0=N0+6
      TMP(N0)=YK(I2+1)
      TMP(N0+1)=YK(I2+2)
      TMP(N0+2)=YK(I2+3)
      I2=I2+3
      DO 250 I=1, NCOL
      I1=NCOL+1-I
      N1=I1*N2-5
      I2=I2+1
      TMP(N1)=YK(I2)
      TMP(N1+2)=TMP(N1-4)
      IF(I1-1) 252, 252, 251
251   I2=I2+1
      TMP(N1+1)=YK(I2)
252   I2=I2+1
      TMP(N1+5)=YK(I2)
250   CONTINUE
999   RETURN
END
FORTRAN
      SUBROUTINE STRESS (II,JJ,KK)
COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8
COMMON NDIM, NROW, NCOL, MM, I1, KML, KM2, KP1, KP2, MFLAG, XM, XLD
COMMON ISW1, ISW2, ISW3
COMMON A
COMMON TMP, YK, YL
COMMON T1, T2, XX, XX1, Z, Z1, Z2

```

*

```

COMMON ZNU, THC, HBO, H1, X0XL, PH3, PH2, XXH, XK
COMMON TE, TI, TO, OC, TC, TD, DDLD
DIMENSION MM(35)
DIMENSION A(1064)
DIMENSION T1(89), T2(89), XX(89), XX1(89), Z(89), Z1(89), Z2(89)
DIMENSION TMP(5184), YK(4, 1296), YL(4,4,324)
DIMENSION ZETA(30)
FORMAT (I3, 1H, I3, 1P9F12.4)
K=KK
J=JJ
NC1=NCOL+1
NR1=NROW+1
SNP3=SINF(PH3)
CSP3=COSF(PH3)
TNP3=SNP3/CSP3
CTP3=CSP3/SNP3
IF (XM) 1, 1, 5
1  XH=XXH
   GO TO 10
5  J1=XMAXOF (J, 1)
J1=MM(J1)
XH= XXH/2.**J1
10 I=II
UX=(DEF(I,J-1,1, KM1)-DEF(I,J+1,1,KP1))/(2.*XH)
UT=(DEF(I+1,J,1, 0)-DEF(I-1,J, 1, 0))/(2.*XK)
VX=(DEF(I * J-1, 2, KM1)-DEF(I-1, J, 1, 0))/(2.*XK)
VT=(DEF(I+1, J, 2, 0)-DEF(I-1, J, 2, 0))/(2.*XK)
WX=(DEF(I, J-1, 3, KM1)-DEF(I, J+1, 3, KP1))/(2.*XH)
WT=(DEF(I+1, J, 3, 0)-DEF(I-1, J, 3, 0))/(2.*XK)
VXX=(DEF(I, J-1, 2, KM1)-2.*DEF(I, J, 2, 0)+DEF(I, J+1, 2, KP1)) /(
1 XH*XH)
VXT=(DEF(I+1, J-1, 2, KM1)-DEF(I+1, J+1, 2, KP1))- DEF(I-1, J-1, 2, KM1)R1P15090
1 ) + DEF(I-1, J+1, 2, KP1)/(4.*XH*XK)
VTX=VXT
VTT=(DEF(I+1,J,2,0)-2.*DEF(I,J,2,0)+DEF(I-1,J,2,0))/XK**2
WXX=(DEF(I,J-1,3,KM1)-2.*DEF(I,J,3,0)+DEF(I,J+1,3,KP1))/XH**2
WXT=(DEF(I+1, J-1, 3, KM1)-DEF(I+1, J+1, 3, KP1)-DEF(I-1, J-1, 3, KM1) +
1 DEF(I-1, J+1, 3, KP1))/(4.*XH*XK)

```

```

WTX=WXT
WTT= (DEF (I+1,J,3,0)-2.*DEF(I,J,3,0)+DEF(I-1,J,3,0))/XK**2
WXX= (DEF(I,J-2,3,KM2)-2.*DEF(I,J-1,3,KM1)+2.*DEF(I,J+1,3,KP1)
      1 -DEF(I,J+2,3,KP2))/(2.*XH**3)
WXTT= (DEF (I+1,J-1,3,KM1)-2.*DEF(I,J-1,3,KM1)+2.*DEF(I,J+1,3,KP1)
      1 )-DEF(I+1,J+1,3,KP1)+DEF(I-1,J-1,3,KM1)-DEF(I-1,J+1,3,KP1)/(2.*RIP15210
      2 XH*XK*XK)
WTTX=WXTT
WTT= (DEF(I+2,J,3,0)-2.*DEF(I+1,J,3,0)+2.*DEF(I-1,J,3,0)-DEF(I-2,B1P15240
      1 J,3,0))/(2.*XK**3)
WXXT= (DEF(I+1,J-1,3,KM1)-2.*DEF(I+1,J,3,0)+2.*DEF(I-1,J,3,0)+
      1 DEF(I+1,J+1,3,KP1)-DEF(I-1,J-1,3,KM1)-DEF(I-1,J+1,3,KP1))/(2.*B1P15220
      2 XH*XH*XK)
X=ZETA(J+1)
HR=HRO+H1*X
D3= THC*SNP3
EPSX= UX
EPST= ( VT/D3 + DEF(I,J,1,0)+DEF(I,J,3,0)/TNP3 )/X
GAM = VX +( UT/D3-DEF(I,J,2,0) )/X
XLX1= -WXX
XLX2= (VT*CTP3/D3-WTT/D3**2)/X**2 -WX/X
XLX12=-(WTX-WT/X)/(X*D3)+(VX-DEF(I,J,2,0))/X/(X*TNP3)
X2LCXX= -WXXX
XLCXT= -WXXT/THC
XLCXTT=-(WXXT-WTT/X)/(X*THC*D3)+(VXT-VT/X)/(X*THC*TNP3)
X2LCTX= (VTX/TNP3-WTTX/D3-2.*((VT/TNP3-WTT/D3)/X)/(D3*X*X)-WXX/X
      1 + WX/X**2
XLCXTT= (VTT*CSP3-WTTT/THC)/(X*D3)**2 - WXT/(THC*X)
X2LXTX= -(WXXT-2.*WTX/X+2.*WT/X**2)/(X*D3) +(VXX-2.*VX/X+2.*DEF(I,B1P15440
      1 J,2,0)/X**2)/(X*TNP3)
      1 IF (MFLAG) 20, 40, 40
      20 CONTINUE
      OMEGAX= -WX
      OMEGATE= DEF (I,J,2,0)/(X*TNP3)- WT/(X*D3)
      PHI=(VX-UT/D3+DEF(I,J,2,0)/X)/2.
      WRITE OUTPUT TAPE 6, 101, J, 1, EPSX, EPST, GAM,XLX1,XLX2,XLX12,
      1 OMEGAX, OMEGAT, PHI
      GO TO 99
      40 CONTINUE

```

```

ANX= EPSX+ZNU*EPST - TC
ANT= FPST+ZNU*FP SX -TC
ANXT= GAM+ HB*XLCXT/(6.*X*TNP3)
ANTX= GAM
AMXT= (1.-ZNU)*XLX12
AMX= XLX1+ZNU*X LX2 -TD/HB
AMT= XLX2+ZNU*X LX1 - TD/HB
AQ T= (XLCTT+ZNU*XLCXT)/(X*SNP3)+(1.-ZNU)*X2LXTX+(2./X+3.*H1/HB)
1*AMXT
AQX = X2Lcxx + ZNU*X2LcTx + 3.*H1/HB*(XLx1 + ZNU*Xlx2) + (1.-ZNU)*B1P15630
1 XLCXTT/(X*SNP3) + (AMX-AMT)/X - 2.*TD*H1/(HB*HB) B1P15640
IF (K) 49, 49, 47 B1P15650
47 YL(1, K, I)=ANX B1P15660
YL(2, K, I)=ANT
YL(3, K, I)=AMX
YL(4, K, I)=AMT
49 CONTINUE
IF (MFLAG) 45, 45, 46
45 WRITE OUTPUT TAPE 6,101,J,I, AMX , AMT, AMXT, AQX , AQT
GO TO 48
46 WRITE OUTPUT TAPE 6,101,J,I, ANX,ANT,ANXT, ANTx
48 CONTINUE
IF (J) 60, 60, 51
51 IF (NR1-J) 70, 70, 52
52 IF (NC1-I) 80, 80, 99
C LOWER BOUNDARY
60 J3=NC1+NR1+2+NC1-I
61 YK(1, J3)= ANXT+HB*AMXT/(X*(1.-ZNU)*TNP3)
YK(2, J3)= ANX
YK(3, J3)= AQX+(1.-ZNU)*XLCTT
YK(4, J3)=AMX
IF (I-NC1) 99, 69, 69
C SPECIAL POINT
69 K1=2*(NC1+NR1)+1
YK(1, K1)=-2.*AMXT
GO TO 80
C UPPER BOUNDARY
70 YK(1, I) = ANXT+HB*HB*AMXT/(X*(1.-ZNU)*TNP3)
YK(2, I) = ANX

```

```

      YK(3, I) = -AQX-(1.-ZNU)*XL.CXT
      YK(4, I) = AMX
      IF (I-NC1) 99, 79, 79
      C      SPECIAL CORNER POINT
      79 K1=2*(NC1+NR1)
            YK(1, K1)=+2.*AMXT
            RIGHT BOUNDARY
      C      J3=NC1+NR1+1-J
            YK(1, J3)=-ANTX
            YK(2, J3)=ANT
            YK(3, J3)= AQT+(1.-ZNU)*X2LXTX
            YK(4, J3)=AMT
      80 RETURN
      FND
      *
      FORTRAN
      SUBROUTINE ZERO (X,N)
      DIMENSION X(8500)
      DO 1 I=1,N
      1 X(I)=0.
      RETURN
      END
      FAP
      COUNT   150
      ENTRY    CLOCK
      ENTRY    WCKA
      ENTRY    WCKP
      SUBROUTINE CLOCK
      *****
      THIS SUBROUTINE PLACES THE CLOCK IN A GIVEN LOCATION SPECIFIED
      BY THE CALL STATEMENT( THAT IS
      CALL CLOCK(LOCATION TO E STOREED IN FORTRAN OR
      CALL CLOCK (FOR ABSOLUTE ASSEMBLIES USE TSX CLOCK
      PZE (LOCATION TO BE STORED) IN FAP
      OR
      SVN (LOCATION TO BE STORED) GIVES THE CLOCK IN FLOATING POINT*B1P16210
      PZE (LOCATION TO BE STORED) GIVES THE CLOCK IN BCD
      *B1P16220 *B1P16230 *B1P16240 *B1P16250 *B1P16260
      IN FORTRAN THE CLOCK WILL ALWAYS BE GIVEN IN FLOATING POINT
      THE CLOCK IS ALSO PRINTED ON-LINE
      ****

```

```

J=N+1-JP
A(J,J)=1.0/A(J,J)
IF (J-1)603,700,603
603 DO600 IP=2,J
      I=J+1-IP
      IPN=I+1
      SUM=-DPSUM (A,I,J,IPN,J)
      600 A(I,J)=SUM/A(I,I)
      700 DO151 J=1,IMAX
          JPO=J+1
          IMO=I-1
          SUM=-DPSUM (A,I,J,J+1,IMO)
          SUM=SUM-A(I,J)
      151 A(I,J)=SUM
          D0901 I=1,N
          D0900 J=1,N
          IF (I-J) 897,897,898
     897 TEMP(J)=DPSUM(A,I,J,J+1,N)
          TFMP(J)=TFMP(J)+A(I,J)
          GO TO 900
     898 TEMP(J)=DPSUM(A,I,J,I,N)
         900 CONTINUE
         D0901 J=1,N
         901 A(I,J)=TEMP(J)
         D0500 I=2,N
         M=N+1-I
         IF (IN(M))502,500,502
     502 ISS=IN(M)
          SUM=A(L,ISS)
          A(L,TSS)=A(L,M)
          503 A(L,M)=SUM
          500 CONTINUE
          GO TO 805
         99 ISING=1
         805 RETURN
        END
        FORTRAN

```


PZE	*+9,,1000		
PZE	*+8,,2000		
PZE	*+7,,3000		
PZE	*+6,,4000		
PZE	*+5,,5000		
PZE	*+4,,6000		
PZE	*+3,,7000		
PZE	*+2,,8000		
PZE	*+1,,9000		
PZE	*+10		
PZE	*+9,,100		
PZE	*+8,,200		
PZE	*+7,,300		
PZE	*+6,,400		
PZE	*+5,,500		
PZE	*+4,,600		
PZE	*+3,,700		
PZE	*+2,,800		
PZE	*+1,,900		
PZE	*+10		
PZE	*+9,,10		
PZE	*+8,,20		
PZE	*+7,,30		
PZE	*+6,,40		
PZE	*+5,,50		
PZE	*+4,,60		
PZE	*+3,,70		
PZE	*+2,,80		
PZE	*+1,,90		
PZE	*+1		
PZF	992		
PZF	993		
PZF	994		
PZF	995		
PZF	996		
PZF	997		
PZF	998		
PZF	999		

R1P17110
B1P17120
B1P17130
B1P17140
B1P17150
B1P17160
B1P17170
B1P17180
R1P17190
B1P17200
B1P17210
B1P17220
B1P17230
B1P17240
B1P17250
B1P17260
B1P17270
B1P17280
B1P17290
B1P17300
R1P17310
B1P17320
B1P17330
B1P17340
B1P17350
B1P17360
B1P17370
B1P17380
B1P17390
B1P17400
B1P17410
R1P17420
R1P17430
B1P17440
B1P17450
R1P17460
B1P17470
B1P17480
R1P17490

```

BCI 8,00000000000100000011000000101000001010000110000111
BCI 8,0010000100100100100100100100100100100100100100100111
BCI 8,01000001000100010001000100010001000100010001000100111
BCI 8,01100001000100010001000100010001000100010001000100111
RCT 8,01100001000100010001000100010001000100010001000100111
RCT 8,10000010001100011000110001100011000110001100011000111
RCT 8,1010001010011010101010101010101010101010101010101111
RCT 8,1100011000111000111000111000111000111000111000111111
RCT 8,11100011000111000111000111000111000111000111000111111
PZE *-1
PZF *-2,,4096
PON *-3
PZE *-4,,7*4096
PZE *-5,,6*4096
PZE *-6,,5*4096
PZE *-7,,4*4096
PZE *-8,,3*4096
PZF *-9,,2*4096
PZE *-10,,1*4096
END FAP
* COUNT
* DPSUM FUNCTION DPSUM(A,I,J,K,M). COMPUTE SUM OF A(I,L)*A(L,J), L=K,1.
* SET DPSUM=0 IF K GREATER THAN M
* SET THE 'VFLD OF RDIM AND ROWDIM TO THE ROW DIMENSION OF A
ENTRY DPSUM
CLA* 5,4 LOAD M
CAS* 4,4 COMPARE WITH K
TRA **+4 M IS BIGGER
TRA **+3 M=K
PXA 0,0 M LESS THAN K SET DPSUM=0
TRA 6,4 AXT+1
SXA AXT+1,2
STD TEST
CLA 1,4 =1
ADD ALL
STA CLA*

```

ARS	18		R1P17890
STA	1		B1P17900
CLA*	4,4		R1P17910
PDX	,2		R1P17920
ARS	18		B1P17930
SUR	=1		R1P17940
XCA			B1P17950
MPY			B1P17960
XCA			B1P17970
ADD	1		B1P17980
PAX	,1		B1P17990
CLA*	3,4		B1P18000
ARS	18		R1P18010
SUB	=1		B1P18020
XCA			B1P18030
MPY			B1P18040
XCA			B1P18050
SSM			B1P18060
ADD		A1L	B1P18070
STA		ALJ	B1P18080
STZ		SUM	B1P18090
STZ		SUM+1	B1P18100
LDQ		***,1	B1P18110
FMP		**,2	R1P18120
DFAO		SUM	R1P18130
DST		SUM	B1P18140
TXI		*+1,1,ROWDIM	R1P18150
TXI		*+1,2,1	B1P18160
TXL		A1L,2,**	B1P18170
TEST		***,1	B1P18180
AXT		***,2	R1P18190
AXT			B1P18200
TRA	6,4		B1P18210
R	COMMON	1	B1P18220
SUM	EQU	R+203	B1P18230
I	PZE		B1P18240
ROWDIM	EQU	72	B1P18250
RDIM	DEC	72	B1P18260
END			B1P18270
*	FAP		

```

COUNT          90
MATRIX MULTIPLICATION IN DOUBLE PRECISION
*   *   *   *   *   *   *   *   *
*   MATM (X, Y, Z, NR, NC, NCY)
*   COMPUTE Z=X*Y.  NR AND NC ARE NUMBER OF ROWS AND COLUMNS IN X.
*   IS NUMBER OF COLUMNS IN Y.  Z=Y O.K. BUT NOT Z=X.
*   ENTRY  MATM
        MATM      AXT,1
                  AXT+1,2
                  AXT+2,4
        SXA       1,4      X-MATRIX
        STA       AX
        CLA       2,4
        STA       AY
        CLA       3,4
        STA       AZ
        CLA*      4,4      NR OF ROWS IN X
        ARS       18
        STA       NR
        CLA*      5,4      NR OF COLUMNS IN X
        ARS       18
        STA       NC
        CLA*      6,4
        ARS       18
        STA       NCY
        CLA       =1
        STO       J
        LDQ       RWDIM
        MPY       J
        XCA
        SSM
        ADD       AZ
        ADD       RWDIM
        ADD       =1
        STA       A7IJ
        LDQ       RWDIM
        MPY       J
        XCA
        SSM
        ADD       AY
B1P18280
B1P18290
B1P18300
B1P18310
NCYB1P18310
B1P18320
B1P18330
B1P18340
B1P18350
B1P18360
B1P18370
B1P18380
B1P18390
B1P18400
B1P18410
B1P18420
B1P18430
B1P18440
B1P18450
B1P18460
B1P18470
B1P18480
B1P18490
B1P18500
B1P18510
B1P18520
B1P18530
B1P18540
B1P18550
B1P18560
B1P18570
A1P18580
R1P18590
B1P18600
R1P18610
R1P18620
B1P18630
B1P18640
B1P18650
B1P18660

```



```

R1P19060
R1P19070
B1P19080
R1P19090
B1P19100
B1P19110
B1P19120
B1P19130
B1P19140
B1P19150
B1P19160
B1P19170
B1P19180
B1P19190
B1P19200
B1P19210
B1P19220
B1P19230
B1P19240
B1P19250
B1P19260
B1P19270
B1P19280
B1P19290
B1P19300
B1P19310
B1P19320
B1P19330
B1P19340
B1P19350
B1P19360
B1P19370
B1P19380
B1P19390
B1P19400
B1P19410
R1P19420
R1P19430
B1P19440

TRA      AXT    *+1
TRA      STO    J
TRA      MTO
TRA      AXT    **,1
AXT      AXT    **,2
AXT      AXT    **,4
TRA      TRA    7,4
DEC      DEC    72
EQU      EQU    72
BOOL   BOOL   130
PZE      PZE    0
END
FAP      COUNT 40
          SUBROUTINE PLBL ( CBLBL, NCR )
ENTRY    PLBL
        AXT,1
        AXT+1,2
NZT*
TRA      CLA    1,4
STA      STA    R1+1
AXT      AXT    6,1
AXT      AXT    0,2
CLA      CLA    RT+6,1
STO    STO    **,2
TNX    TNX    AXT,1,1
TXJ    TXJ    R1,2,1
CLAS   CLA    1,4
STA    STA    UP+1
AXT    AXT    12,1

*      *PLBL
RIGHT   CLA    1,4
STA      STA    R1+1
AXT      AXT    6,1
AXT      AXT    0,2
CLA      CLA    RT+6,1
STO    STO    **,2
TNX    TNX    AXT,1,1
TXJ    TXJ    R1,2,1
CLAS   CLA    1,4
STA    STA    UP+1
AXT    AXT    12,1

```

```

      UP          0,2
      CLA        UPP+12,1
      STO        **,2
      TNX        AXT,1,1
      TXI        UP,2,1
      AXT        **,1
      AXT        **,2
      TRA        3,4
      BCI        6,   RIGHT BOUNDARY
      BCI        6,   CURVE 1= UPPER BOUNDARY
      BCI        6,   CURVF 2= LOWER BOUNDARY
      END

      *   FAP          COUNT    80
      *PLTLBL  SUBROUTINE PLTLBL (DISP, STRSS, ORDLBL, ABLBL, BOND )
      PLTLBL ENTRY PLTLBL
      PLTLBL SXA   AXT,1
      PLTLBL SXA   AXT+1,2
      CLA     1,4
      STA     D1+1
      AXT     9,1
      AXT     0,?
      CLA     DISP+9,1
      STO     **,2
      TNX     *+2,1,1
      TXI     D1,2,1
      CLA     2,4
      STA     S1+1
      AXT     9,1
      AXT     0,2
      CLA     STRSS+9,1
      STO     **,2
      TNX     *+2,1,1
      TXI     S1,2,1
      CLA     3,4
      STA     01+1
      AXT     66,1
      AXT     0,2
      CLA     ORDU+66,1

```

STO **,2
 TNX **+2,1,1
 TXI 01,2,1
 CLA 4,4
 STA A1+1
 AXT 6,1
 AXT 0,2
 AXT ARLRL+6,1
A1 **,2
 STO **+2,1,1
 TNX TXI A1,2,1
 CLA 5,4
 STA B1+1
 AXT 9,1
 AXT 0,2
B1 CLA BON+9,1
 STO **,2
 TNX **+2,1,1
 TXI B1,2,1
 AXT **,1
 AXT **,2
 TRA 6,4
 BCI 6,
 BCI 6,
 ORDW BCI 6,
 ORDV BCI 6,
 AXT TXI 6,4
 AXT 6,4
 TRA 6,4
 BCI 6,
 BCI 6,
 ORDNX BCI 6,
 ORDNT BCI 6,
 ORDNM BCI 6,
 ORDMT BCI 6,
 ORDN BCI 6,
 ORDNR BCI 6,
 ORDQ BCI 6,
 ORDM BCI 6,
 ABLBL BCI 6,
 DISP BCI 6,
 STRSS BCI 6,
 BON BCI 6,
 END
 FAP

U V W
 NX NTTHETA
 MX MTTHETA
 NTAN
 NNORM
 Q
 M
 THETA

FIG. CONE DISPLACEMENT COMPONENTS
 ϵ_{13} CC-1E STRESS RESULTANTS
 σ_{13} FOUNDRY STRESS RESULTANTS

```

* COUNT    70
FUNCTION QDPSUM (A, I, J, K2, J2)
ENTRY     QDPSUM
          SXA      AXT,1
          SXA      AXT+1,2
          SXA      AXT+2,4
          CLA      1,4
          STA      DP1
          STA      DP1+1
          LXA      ROWD,1
          SXD      DP2,1
          CLA*     2,4
          ARS      18
          STA      I
          CLA*     4,4
          ARS      18
          STA      K2
          ADD      K
          SUB     I
          XCA      ROWD
          MPY
          XCA
          ADD      I
          SUR      =1
          PAX      *1
          CLA*     3,4
          ARS      18
          STA      I
          CLA      ROWD
          ADD      =1
          SUB     I
          TZE      DP
          CLA      ROWD
          SUB     =1
          PAC      ,2
          SXD      DP3,2
          CLA      1
          AND     K
          SUR     K2
          R1P20230
          R1P20240
          B1P20250
          R1P20260
          B1P20270
          R1P20280
          B1P20290
          B1P20300
          B1P20310
          B1P20320
          B1P20330
          B1P20340
          B1P20350
          R1P20360
          B1P20370
          B1P20380
          R1P20390
          R1P20400
          B1P20410
          R1P20420
          B1P20430
          B1P20440
          R1P20450
          R1P20460
          R1P20470
          B1P20480
          R1P20490
          R1P20500
          B1P20510
          R1P20520
          B1P20530
          B1P20540
          B1P20550
          B1P20560
          R1P20570
          B1P20580
          R1P20590
          R1P20600
          R1P20610

```

XCA	MPY	XCA	ROWD						
XCA	SUB	=1							
ADD	K2								
PAX	*2								
TRA	DPO								
DP	AXT	1•2							
	SXD	DP3,?							
	CLA	K							
	ADD	K							
	ADD	=1							
XCA	MPY	ROWD							
XCA	ADD	K2							
	SUB	=1							
	PAX	*2							
DPO	CLA*	5•4							
	ARS	18							
	SUB	K2							
	ADD	=1							
	PAX	*4							
	STZ	TEMP							
	STZ	TEMP+1							
DP1	LDQ	**,1							
	FMP	**,2							
	DFAD	TEMP							
	DST	TEMP							
DP2	TXI	*+1•1,**							
DP3	TXI	*+1•2,**							
	TXI	DP1•4,1							
AXT	AXT	**,1							
	AXT	**,2							
	AXT	**,4							
	TRA	6•4							
	DFC	270							
	DEC	5							
	PZE	I							

```

K2      PZE      77774
TEMP    BOOL
END
*      FAP      COUNT 170
*      *      SURROUTINES RTAPE, WTAPE, BACK, AND RESET
          ENTRY WTAPF
          ENTRY RTAPF
          ENTRY RFW
          ENTRY BACK
          ENTRY RESET
          CLA  WRS
          STD  WRTP
          STZ  FLAG1
          TRA  RFFIN
          CLA  RDS
          STD  WRTP
          STL  FLAG1
          SXA  AXT•1
          SXA  AXT+1,2
          STZ  FLAG
          CLA*  1,4
          STA  RSR
          ANA  MASK
          TZE  *+3
          STL  FLAG2
          TRA  *+2
          STZ  FLAG2
          NZT*  4,4
          TRA  WR
          TZE  CKB
          CK   TCOA
          CKA  TRCA
          TCOB
          TRA  ERR
          TRA  AXT
          *      *
          TRCR
          TRA  ERR
          TRA  AXT
          ZET  FLAG
          TRA  BLNK
          NO
          TAPE ERROR. IS THIS THE FIRST TIME
          NO
R1P21010
B1P21020
B1P21030
B1P21040
B1P21050
R1P21060
R1P21070
B1P21080
B1P21090
B1P21100
B1P21110
B1P21120
B1P21130
B1P21140
R1P21150
R1P21160
B1P21170
R1P21180
B1P21190
B1P21200
R1P21210
R1P21220
R1P21230
B1P21240
B1P21250
B1P21260
B1P21270
B1P21280
B1P21290
B1P21300
B1P21310
B1P21320
B1P21330
B1P21340
B1P21350
R1P21360
B1P21370
B1P21380
B1P21390

```

STL	FLAG	**	
BSR	CLA*	3•4	
RSR	IOC	IOC	WORD COUNT
WR	18	18	
STD	ADD	2•4	BOTTOM OF ARRAY IN AC
ARS	ADD	=1	
SSM	STA	IOC	
	CLA*	1•4	SET TAPE UNIT ADDRESS
	STA	WRTP	
	ANA	TPNR	PICK OUT LAST DIGIT
	PAX	,1	TAPE M. M TO XR 1
	CLA	TPCNT+1,1	
	STA	LD1	
	STA	COMP	
	STA	STORF	
	PDX	•2	
	LDQ	***,2	IF RERUN, DONT BUMP COUNTERS
	ZET	FLAG	
	TRA	RERUN	
	SSP	NOT A BACKSPACE SO SIGN PLUS	
	ADD	ONE	
	PDX	•2	
	STD	TPCNT+1,1	
	STA	TPCNT+1,1	
	ZFT	FLAG1	IS IT READ OR WRITE
	TRA	WR1	RFAD OPERATIION
	XCA	WRITF OPERATION.	MUST MAKE UP NEXT RECORD ID NR.
	ADD	ONE	
	ADD	=1	
	STORE	***,2	STORF NEXT RECORD ID WORD IN TABLE
	STO	IDENT	FIRST WORD OF RECORD
	NZT	FLAG2	CHANNEL A OR B
	TRA	TPR	
	TPA	TCOA	*
		TRCA	*+1
		XEC	WRTP
		RCHA	ICID

```

LCHA FLAG1 IF READING, GO CHECK RECORD ID
ZET COMP
TRA FLAG IS THIS A RERUN
ZET CKA YES. GO AND CHECK FOR REDUNDANCY
TRA AXT NO. GO BACK AND COMPUTE SOME MORE
* TCOB *+1
TRCR XEC WRTP
RCHB ICID
LCHR LOC
ZET FLAG1
TRA COMP
ZFT FLAG
TRA CKR
TRA AXT
CLA **+2
SUB IDENT DOES FIRST WORD OF RECORD AGREE WITH ID
TNZ SHIFT NO. TRY ANOTHER RECORD
STP TPCNT+1,1
NZA FLAG YES. IS THIS A RERUN
TRA AXT IF NOT, GO RACK
CLA FLAG2
TRA CK
ZFT FLAG1
TRA WR1 RESET ID WORD
XCA STORE+1
TRA ZET IS THIS A READ
TRA OUT IF SO GIVE UP
BSR
XEC WRTP
XEC WRTP
XEC WRTP
MAX
CLA =1
SUB OUT QUIT AFTFR MAX TIMES
TMI MAX
STO INFNT
CLA

```

TRA	SHIFT	STORE-1
CLA	MAX	
SUB	=1	
TMI	OUT	
STO	MAX	
CLA	TPCNT+1,1	
TPL	WRI	LAST ACTIVITY WAS READ OR WRITE SO GO AHEAD
XEC	BSR	LAST ACTIVITY WAS BACKSPACE. MUST GO BACK
XFC	BSR	
TRA	WR1	LOOK FOR MISSING RECORD AGAIN
AXT	AXT	***,1
	AXT	***,2
	TRA	5,4
	CALL	DUMP
OUT	CLA*	1,4
REW	STA	**+,1
	REW	**
	SXA	AX,1
	ANA	TPNR
	PAX	,1
	PXA	0,0
	STD	TPCNT+1,1
AX	AXT	***,1
	TRA	2,4
	CLA*	1,4
BACK	STA	BSR
	XEC	BSR
	SXA	BX,1
	ANA	TPNR
	PAX	,1
	CLA	TPCNT+1,1
	SSP	ONF
	SUB	
BX	SSM	TPCNT+1,1
	STO	,1
	AXT	2,4
	TRA	NOP
	RESET	PXA

```

STD      TPCNT-3
STD      TPCNT-2
STD      TPCNT-1
STD      TPCNT
TRA      1*4
      IOST IDENT.,,1
      IORT 0,,0
      WRS   ***
      WRS   RDS  ***
      PZE   TBL4
      PZE   TBL3
      PZE   TBL2
      PZE   TBL1
TPCNT    OCT   7
      TPNR  OCT   000000010000
      MASK  DFC   40
      MAX   OCT   1000000
      ONF   OCT
      FLAG
      FLAG1
      FLAG2
      IDENT PZE
      TBL1  BES  80
      TBL2  BES  80
      TRL3  BES  80
      TBL4  BES  80
      END
      CHAIN (2,2)
      * * FORTRAN
      INDEX (1270)
C      PROGRAM TO CONTROL PLOTTING FROM SCRATCH TAPE
C      CAN PLOT SEQUENTIAL GRAPHS EACH HAVING SEVERAL CURVES
C      NXP = NUMBER OF VALUES OF INDEPENDENT VARIABLE FOR A GIVEN GRAPH
C      NCRVS = NUMBER OF CURVES TO BE PLOTTED ON A GIVEN GRAPH
C      NPTS = NUMBER OF INTERVALS BETWEEN DEPENDENT VARIABLE VALUES
C      AT WHICH IDENTIFYING SYMBOLS ARE TO BE PLACED
C      IF NEND = 0, OTHER GRAPHS ARE TO FOLLOW
C      IF NEND = 1, CURRENT GRAPH IS THE LAST
      B1P22570
      B1P22580
      B1P22590
      B1P22600
      R1P22610
      B1P22620
      B1P22630
      B1P22640
      B1P22650
      R1P22660
      B1P22670
      B1P22680
      B1P22690
      B1P22700
      R1P22710
      B1P22720
      R1P22730
      B1P22740
      R1P22750
      R1P22760
      B1P22770
      B1P22780
      B1P22790
      B1P22800
      R1P22810
      B1P22820
      R1P22830
      B1P22840
      B1P22850
      R1P22860
      B1P22870
      B1P22880
      B1P22890
      B1P22900
      B1P22910
      B1P22920
      B1P22930
      B1P22940
      B1P22950

```

```

C IFNFLAG = 0, CONTROL WILL BE RETURNED TO CHAIN (1,3)
C IFNFLAG = 1, RUN WILL BE TERMINATED BY CALL EXIT
C DIMENSION XP(200),YP(200,4),ABLBL(6),ORDLBL(6),GPHLBL(9),
1 CILBL(6,4),RFCORD(12),YT(200)
1 KP=15
REWIND KP
20 READ TAPE KP, RECORD
READ TAPE KP, NXP, NCRVS, NPTS, NEND, NFLAG
READ TAPE KP, ABLBL, ORDLBL, GPHLBL
READ TAPE KP, CILBL
DO 32 KT = 1,NXP
32 READ TAPE KP, XP(KT)
DO 33 L = 1,NCRVS
DO 33 KT = 1,NXP
READ TAPE KP, YT(KT)
33 YP(KT,L) = YT(KT)
CALL PLOTS(NXP,NCRVS,NPTS,NEND,NFLAG,XP,YP,RECORD,ABLBL,ORDLBL,
1 GPHLBL,CILBL)
1 IF(NEND)20,20,21
21 IF(NFLAG)40,40,41
40 CALL CHAIN (1,2)
41 CALL FXIT
END
* FORTRAN
* SUBROUTINE PLOTS(NXP,NCRVS,NPTS,NEND,NFLAG,X,Y,RECORD,ABLBL,
1 ORDLBL,GPHLBL,CILBL)
C SC 4020 ROUTINE FOR PLOTTING SEVERAL CURVES ON A SINGLE GRAPH
C INDEX (1280)
DIMENSION X(200),Y(200,4),ABLBL(6),ORDLBL(6),GPHLBL(9),RECORD(12)
DIMENSION KX1(4),KY1(4),KX2(4),CILBL(6,4),CLBL(6),
1 ORD(6),GPHL(6),YP(200),MRK(4)
WRITE OUTPUT TAPE 6,10
10 FORMAT(15HO PLOT CALLED )
F TARI V
CALL CAMRAV(9)
XL = X(1)
XR = X(1)
DO 20 I = 2,NXP
XL = MIN1F(XL,X(I))

```

```

20 XR = MAX1F(XR,X(1))
DC = 20.0
CALL DXYV(1,XL,XR,DX,N,II,NX,DC,IERR)
KX1(1) = 185
KX1(2) = 185
KX1(3) = 585
KX1(4) = 585
KY1(1) = 985
KY1(2) = 955
KY1(3) = 985
KY1(4) = 955
KX2(1) = 200
KX2(2) = 200
KX2(3) = 600
KX2(4) = 600
MRK(1) = 38
MRK(2) = 55
MRK(3) = 63
MRK(4) = 53
YB = 0.0
YT = 0.0
DO 40 J = 1,NCRVS
DO 40 I = 2,NXP
YB = MIN1F(YB,Y(I,J))
40 YT = MAX1F(YT,Y(I,J))
YB = YR*I*10
YT = YT*I*10
L = 1
CALL DXYV(2,YB,YT,DX,M,JJ,NY,DC,IERR1)
NX = + 3
NY=-2
II = -II
JJ = -JJ
CALL SFTMIV(100,10,70,100)
CALL GRIDIV(L,XL,XR,YB,YT,DX,DY,N,M,II,JJ,NX,NY)
DO 60 K = 1,6
60 ORDL(K) = ORDLBL(K)
CALL CHSIZV(2,2)
CALL RITSTV(12,18,TARL1V)

```

```

CALL RITE2V(75,330,1023,180,1,36,1,ORDL,NLAST) B1P23740.
CALL RITE2V(330,57,1023,90,1,36,1,ABLBL,NLAST) B1P23750
CALL PRINTV(72,RECORD,100,1015), B1P23760
      DO 61 K = 1,9 B1P23770
61   GPHL(K) = GPHLBL(K) B1P23780
      CALL CHSIZV(3,4) B1P23790
      CALL RITSTV(18,30,TARL1V) R1P23800
      CALL RITE2V(40,20,1023,90,2,54,1,GPHL,NLAST) B1P23810
      DO 70 J = 1,NCRVS B1P23820
        YP(1) = Y(1,J) B1P23830
        NX1 = NXV(X(1)) B1P23840
        NY1 = NYV(YP(1)) B1P23850
        DO 50 I = 1,NXP B1P23860
          YP(I) = Y(I,J) B1P23870
          NX2 = NXV(X(I)) B1P23880
          NY2 = NYV(YP(I)) B1P23890
          IF(NX2*NY2)45,50,45 B1P23890
45   CALL LINEV(NX1,NY1,NX2,NY2) B1P23910
      NX1 = NX2 B1P23920
      NY1 = NY2 B1P23930
      50 CONTINUE B1P23940
      MRKPT = MRK(J) B1P23950
      CALL APLOTV(NXP,X,YP,NPTS,NPTS,1,MRKPT,IERR) B1P23960
      KX = KX1(J) B1P23970
      KY = KY1(J) B1P23980
      NS = J B1P23990
      CALL POINTV(KX,KY,NS,ANY) B1P24000
      KXC = KX2(J) B1P24010
      DO 93 K = 1,6 B1P24020
93   CLBL(K) = CILBL(K,J) B1P24030
92   CALL PRINTV(36,CLBL,KXC,KY) B1P24040
70   CONTINUE B1P24050
      IF(NEND)90,90,91 B1P24060
91   CALL EOFTV B1P24070
      WRITE OUTPUT TAPE 6,80 B1P24080
80   FORMAT(22HO) PLOTTING COMPLETED B1P24090
90   RETURN B1P24100
      END R1P24110

```